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Diathermy in Medical and Surgical Practice

BY

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PREFACE

The aim of this little book is to serve as a guide to students and practitioners who wish to master the technique of Diathermy, and to appraise its place in the treatment of disease.

This method of treatment has now been used on a scale sufficiently large to justify the claim that it is a valuable and promising therapeutic agent, both in Medicine and in Surgery.

While recording my own results, I have availed myself of the experience of other workers in this field of electro-therapeutics. I have also touched upon ionization and other methods of treatment which are sometimes combined with Diathermy.

My thanks are due to Mr. Herbert Frankling for the description he has supplied of the suprapubic method of operating diathermically on vesical papillomata, and of the diathermic treatment of malignant disease of the tongue.

Those who have had experience of this therapeutic method will agree that it should not be given by unqualified operators. No kind of electrical treatment, indeed, should be administered by the untrained. If dangers are to be avoided and beneficial results obtained, the employment of these agents should be limited to those who have a working knowledge of their effects in diseased conditions. At present anyone who possesses a dry battery may give electrical treatment. That is a deplorable state of things which will, I hope, in a not remote future be remedied.

C. S.

Harrogate,
February, 1920.

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DIATHERMY IN MEDICAL AND SURGICAL PRACTICE

PART I.—TECHNIQUE

CHAPTER I

DEFINITION AND HISTORICAL NOTES

Professor Zimmern of Paris has defined diathermy as "a form of thermo-therapy which utilizes electrical energy for the production of thermal effects in the depths of the tissues." This definition appears to me a good one. Other names besides diathermy are sometimes employed to denote the heating effects of high-frequency currents. "Endothermy" is occasionally used, and is preferred by some workers because the heating effect is produced in the tissues themselves, i.e. it is endogenous in origin. "Thermo-penetration" and "transthermy" are other terms used. The word diathermy, however, is the one which has been generally adopted to describe the heating-through effects of these special high-frequency currents.

Diathermy is really the high-frequency current under another name, and for this reason we must regard Prof. d'Arsonval of Paris as the pioneer of this method of treatment.

Franz Nagelschmidt of Berlin modified and developed the high-frequency machine in order to obtain marked thermal effects, and called the treatment diathermy.

It is well known that electrical currents heat the conductors through which they pass, but it is impossible to raise the internal temperature of the body by the ordinary continuous current, on account of the pain produced by strong applications. The same reason prevents the use of the faradic current for this purpose ; this current, moreover, produces violent muscular contractions.

In order to raise the internal temperature of the body we must employ currents which reverse their direction many thousands of times per second, i.e. high-frequency currents.

In 1890, d'Arsonval developed and repeated the experiments of Ward, and showed that if currents reversed their direction beyond 5,000 times per second, the muscular contractions diminished in proportion to any increased periodicity ; and Tesla, in 1891, showed that by using the rapid oscillatory discharge from Leyden jars, large currents of high potential could be passed through the human body without harmful or painful effects, currents powerful enough to light up several incandescent lamps.

The probable explanation of this absence of painful sensations is that the rapid oscillations of the current prevent the occurrence of ionic effects.

It was in February, 1891, that d'Arsonval first used high-frequency currents to traverse the human body, and in a communication to the Société de Biologie he stated that he had personally passed 3 amperes without any sensation except that of heat. Subsequently, Somerville studied the thermal effects of these currents. In 1896, d'Arsonval passed 500 milliamperes through his subjects, who noted distinct heating effects, and in 1898 he commenced to employ high-frequency currents in the treatment of disease. Then followed the works of Bordier and Lecomte, Bouiniot, Wertheim, Salomanson, Zimmern and Turchini. In 1898, at a Congress in Budapest, Nagelschmidt demonstrated a diathermy apparatus designed by himself, and in 1907, at Dresden, he demonstrated the "heating-through" of tissues by high-frequency currents, and suggested their use in the treatment of diseases of the circulation and the joints.

In 1908 a conjoint paper written by von Berndt, von Preiss and von Zeynech laid stress on the diathermic effect of high-frequency currents and advocated their use in the treatment of joint diseases. In 1910, Eugène Doyen communicated to the International Congress of Physiotherapy an account of the treatment of cancer by means of electrically-produced heat.

The thermal effects produced by high-frequency currents and the therapeutic use of diathermy were brought prominently to our notice by Nagelschmidt in 1910. He first demonstrated their use in this country at St. Bartholomew's Hospital with a machine made by Messrs. Siemens Bros. to his design. The various types of high-frequency apparatus previous to the introduction of a diathermy machine did not produce oscillations sufficiently sustained to have strong thermal effects, and, moreover, their voltage was unnecessarily high. The significance of these facts was not at first appreciated.

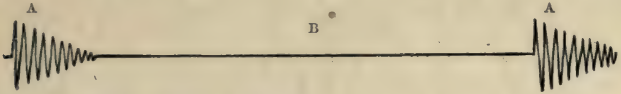

Fig. 1.—Diagrammatic representation of the intermittent discharge from the d'Arsonval type of apparatus.

A, Discharge time, $\frac{1}{50000}$ sec. B, Interval between each discharge, $\frac{1}{100}$ sec.

Fig. 1 shows diagrammatically the intermittent oscillations produced by the ordinary type of d'Arsonval apparatus. The voltage was needlessly high, 15,000–30,000 volts or more, and the amperage low. The patient only received treatment for a very small fraction of the time he was on the couch, it being calculated that during the séance, lasting ten minutes, the patient was only subjected to the high-frequency oscillations for a few seconds.

Fig. 2 shows diagrammatically the train of sustained oscillations produced by a diathermy machine. The voltage is low, 200–1,000, and the amperage high, up to 3 amp. or more.

With the modern diathermy apparatus, regular, more or less sustained waves of very high frequency, up to 3,000,000 per second, can be obtained, and large currents up to 3 amp. can be passed through the body without any sensation except that of heat. The current is measured by a hot-wire ammeter—the expansion of wire heated by the passage of a current of electricity being used to measure the amount of current passing. The construction of a hot-wire instrument is illustrated by Fig. 3. C is the wire

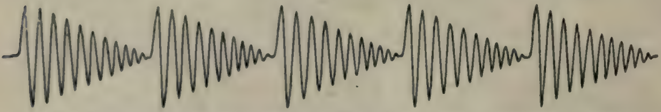

Fig. 2.—Diagrammatic representation of the more sustained train of oscillations produced by a modern diathermy apparatus.

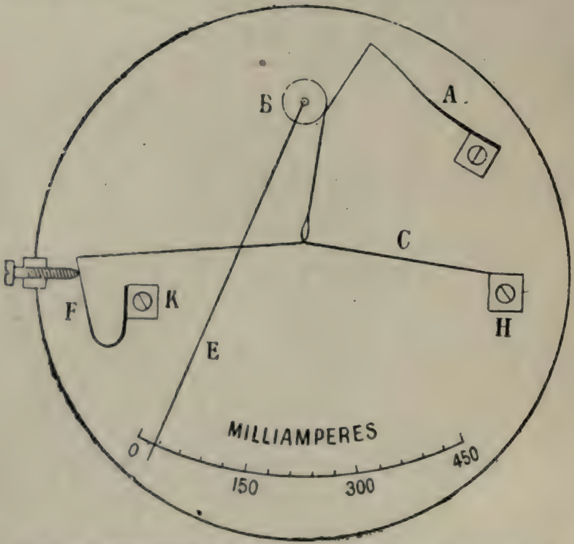

Fig. 3.—Arrangement of hot-wire instrument, calibrated as a milliamperemeter.

(*By permission, from Lewis Jones's "Medical Electricity."*)

stretched between H and K by a spring, F. A thread attached to its centre passes round B to a spring, A. When the wire expands, the pull of A deflects it, and the movement is communicated through B to the pointer, E.

In diathermy we are employing the heating effects of high-frequency currents, the heat being generated in the tissues traversed by the current owing to the resistance they offer to the passage of the current through them.

CHAPTER II

THE PRODUCTION OF HIGH-FREQUENCY CURRENTS

We have aready indicated that high-frequency currents are currents which change their direction, or oscillate to and fro, many thousands of times per second. How are these currents produced ? To understand this we must refer to the **Leyden jar**, or **condenser.** It was Prof. Joseph Henry of Washington who first asserted that the discharge from a Leyden jar was oscillatory in nature. A Leyden jar (Fig. 4) consists of a glass bottle or jar lined on the inside and outside with tinfoil to within about 3 in. of the top. The mouth of the jar is filled with a cork or other stopper of insulating material which is perforated in the centre by a hole. Through this hole passes a stout wire. To the bottom end of the wire is attached a chain which is sufficiently long to make good contact with the tinfoil lining the inside of the jar. The top of the wire terminates in a knob. The sheets of tinfoil are sometimes called the armatures of the condenser, the glass acting as a dielectric. In order to charge the jar, the outer coating is connected to earth. This procedure enables the inner coating of the jar to hold a larger quantity of electricity than it would otherwise retain, and it is for this reason that the term condenser is used when speaking of such types of apparatus. The inner coating of

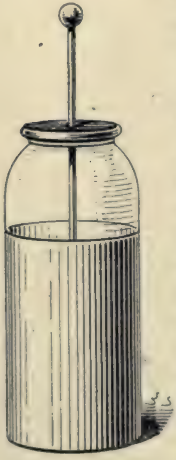
Fig. 4.—Leyden jar.

the jar is charged by connecting it to a high-tension electrical machine, such as a large induction coil. The charge communicated to the inner coat causes, by the principle of inductance, a charge of opposite sign to be given to the outer coat. In order to discharge the jar a metallic conductor connected with the outer coating is brought near to the knob on the top of the jar, and a spark passes between the two. This spark is in reality made up of a number of sparks passing alternately from the knob to the conductor connected to the outer coat, and vice versa, at an enormous rate, which may in some cases reach a frequency of millions a second. The discharge is illustrated diagrammatically by Fig. 5.

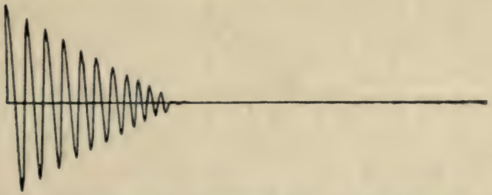

Fig. 5.—Diagrammatic representation of the discharge of a Leyden jar.

The number of oscillations depends upon the size of the condensers and the resistance of the circuit through which the induced currents flow. An analogy which is commonly used to describe the discharge of a condenser is that of water flowing between two vessels connected by a pipe at their lower ends. The vessels are placed at the same height, one is filled with water, the other is left empty. If, now, a tap is suddenly opened and water allowed to flow along the pipe into the empty vessel, its manner of filling this will depend upon the diameter of the pipe. If the pipe has a small diameter, and therefore high resistance, the water will flow slowly and gradually until its level in the second vessel is the same as that in the first. If, however, the connecting pipe is of large diameter, the water will rush into the second vessel, and equilibrium will only be reached in the two vessels after a series of oscillations in which the height of the water is greater first in one and then in the other. Another analogy used is that of a vibrating spring or reed. The reader who wishes to know more about this subject may refer to Sir Oliver Lodge's "Modern Views of Electricity," Lecture III., p. 387.

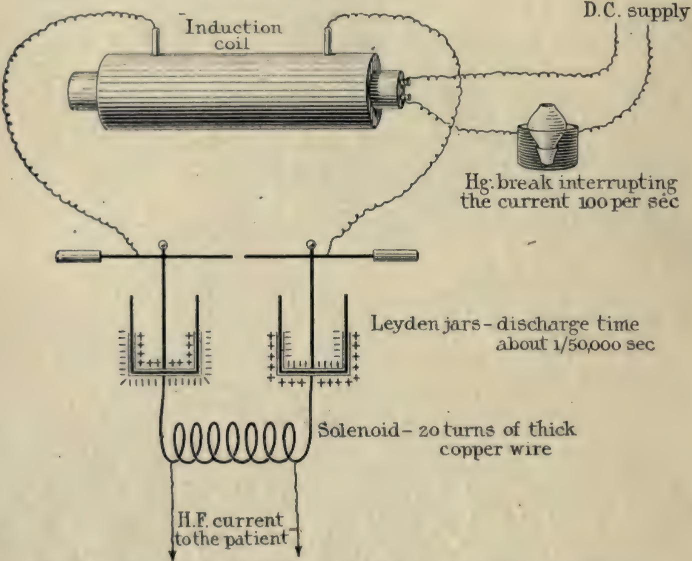
Induction coil
D.C. supply
Hg: break interrupting the current 100 per sec
Leyden jars - discharge time about 1/50,000 sec
Solenoid - 20 turns of thick copper wire
H.F. current to the patient

Fig. 6.—Diagram of d'Arsonval type of high-frequency apparatus.

In the d'Arsonval type of high-frequency apparatus (Fig. 6) the outer coatings of two Leyden jars are connected by means of a **helix** or **solenoid** of thick copper wire; the wire need not necessarily be solid, for the reasons given elsewhere (p. 23). When the inner coats of the jars are charged by the induction coil to a sufficient potential, they discharge across the spark gap, and also through the solenoid, which becomes the seat of induced high-frequency currents of very high potential, 100,000 or more volts. If a pair of electrodes is held one in each hand and connected to the ends of the helix of wire, the body will be traversed by high-frequency currents of considerable magnitude. An incandescent lamp placed in series with a patient will glow brightly, and yet no shock is felt by the patient, provided he grasps the electrodes firmly. Enormous as is the difference in potential between the outer coatings of the two Leyden jars, it is practically unaffected, although they are short-circuited by the coil of copper wire forming the solenoid. This is due to the fact that the wire takes the form of a spiral with closely adjacent coils. Inasmuch as, directly an electric current commences to flow in a coil of wire, a flow of current is induced in a neighbouring coil in the opposite direction, it can be readily understood that, in the case of high-frequency currents, which flow only for a moment of time in one direction before they reverse and flow in the opposite direction, the resistance of the opposing induced currents in the coils of the solenoid must be very high. Currents of still higher voltage can be produced by winding a second coil of wire round the solenoid. In **Tesla's transformer** this second coil of wire is placed inside the primary solenoid. Another method of raising the tension of high-frequency currents is by means of what is known as **Oudin's resonator**, described at p. 42. Sometimes the primary solenoid is so enlarged as to enclose a patient either standing or sitting. The patient is not in actual contact with the solenoid, but, by the principle of induction, large currents are induced in the body. This method of treatment is called auto-conduction.

CHAPTER III

THE DIATHERMY APPARATUS

Various types of machines have been evolved by different makers. We will first consider the general principles upon which they work, and later give a short description of some of the chief types of machine. The direct current is not generally suitable for operating diathermy machines for medical purposes; unless the pressure exceeds 250 volts the machine will not work smoothly; for this a pressure of about 500 volts is required. If this voltage is not available, and there is no alternating-current supply, it is necessary to convert the direct into an alternating current by means of a motor generator capable of giving an output of at least 100 volts at 10 amp. This means the installation of special cables, the ordinary wiring of a house not being heavy enough to carry the current. Several makes of diathermy machine take about 15 amp. in the primary winding of the transformer, and the installation of cables capable of carrying 20 amp. is advisable. When ordering a diathermy machine it is therefore necessary to know the particulars of the electric-lighting supply. If the supply is an alternating one, it is only necessary to provide cables capable of carrying 20 amp., and instruct the makers to have the machine wound for the particular voltage of the local supply.

We have already indicated that d'Arsonval high-frequency currents and diathermy currents have certain characteristic differences; in the former the oscillations are not sustained, have high voltage and low amperage, while the latter are characterized by more sustained oscillations, low voltage, and high amperage. These differences are due to the fact that diathermy currents are not produced by means of a high-tension induction coil worked by a break, and Leyden jars discharging across two metal rods, as is the d'Arsonval type of current. (*See* Fig. 6.) In the place of the Leyden jars we have condensers made up of sheets of thin metal insulated from one another by glass, paraffin-wax paper, or other material. The condensers are charged from the alternating-current main by means of a static transformer, and their capacity is greater than that of Leyden jars.

The principle of the **static transformer** is perfectly simple (Fig. 7). A core of soft iron is made up, usually in the form of a square, insulated wire is wound round one side of the iron core, and connected to the alternating-current supply. Round the opposite side of the iron core a second separate coil of wire is wound, and the number of turns comprising this second coil of wire, compared with those in the first coil, determines the voltage and amperage that go to charge the condensers. For the sake of argument, we will assume that the first coil of wire is made up of 100 turns of wire charged at 100 volts and 1 amp. from the alternating-current supply. If the second coil of wire has 10 turns, 10 amp. will be obtained from it at 10 volts; if there are only 5 turns, 20 amp. at 5 volts.

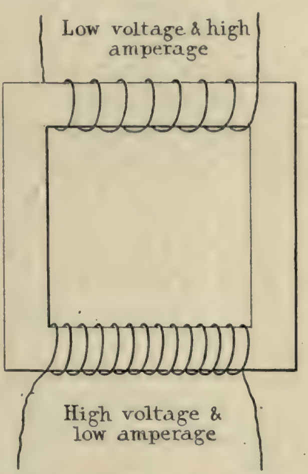

Fig. 7.—Diagram of a static transformer.

The charged condensers discharge across a **spark gap**, the design of which varies in the different makes of diathermy machine. Usually the spark gap consists of one or more pairs of large copper discs, which nearly touch one another. It is one of the most important and most sensitive parts of the machine. A very slight alteration in the width of the gap makes an appreciable difference in the amount of current passing through the ammeter. The spark gap must be kept in perfect order, and scrupulously cleaned from time to time. It is in the design of the spark gap that one of the chief differences between various makes of machines consists. The spark gap tends to become overheated, and if this takes place the current diminishes. Various devices are employed to dissipate the heat evolved at the gap. In some machines copper blocks provided with ribs to radiate the heat are used, and, in addition, there is vapour of alcohol in the gap. The sparks decompose the alcohol, and hydrogen is formed, which is a much better conductor of heat than air. Coal gas may be used in the same way, and the width of the spark gap can be adjusted in certain types of machine while the current is running. Water-cooling devices are also used, and sometimes a stream of air is directed over the metal discs by a fan. The rapid discharge of the large-capacity condensers across the spark gap causes a sustained train of high-frequency oscillations to be set up in a coil of wire (solenoid) connected to the other coats of the condensers. The current to the patient is not usually taken directly from the solenoid, which functions as a primary high-frequency coil, but from a second coil which may be moved nearer to or farther from the primary coil. In some makes of machines tappings are taken off the secondary high-frequency coil in order to vary the voltage obtainable. Fig. 8 shows roughly the general plan of a diathermy apparatus.

The following is a short description of three representative types of diathermy apparatus of which I have had experience. The machines vary chiefly in the method of regulating the current, and in the design of the spark gap.

1. **Watson's apparatus.**—This apparatus is one of the latest type, the high-tension current required to charge the condenser being furnished by means of a true wound step-up *transformer* working on alternating current. The transformer has a capacity of about 800 watts, and is wound for about 5,000 volts.

The *condenser* is shown mounted in a box by the side of the transformer, and is connected across the secondary terminals. (Fig. 9.)

Of the *spark gap* (Fig. 10), across which the condenser discharges, many types have been evolved. The best design is the one that provides for the discharge to take place in an atmosphere of coal gas, and that illustrated is the most recent form of this type. It is very desirable to provide means of regulating the width of spark gap, as by this means the frequency of the oscillating current given to the patient can be nicely adjusted.

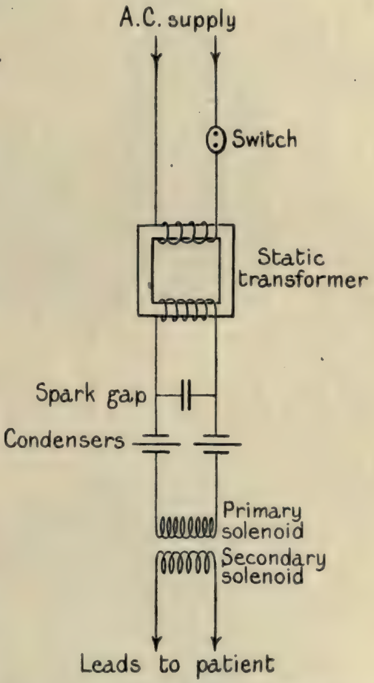

Fig. 8.—General plan of a diathermy apparatus.

The gap consists of an aluminium cylindrical body, *m*, the opposite ends of which are removable by thumbscrews,

G. These ends consist of aluminium rings with mica central portions, through the centres of which are fitted the fixed spark-gap *electrodes*. These electrodes are bent at a right angle, so that the surface across which the sparks play is horizontal, the actual sparks themselves passing vertically.

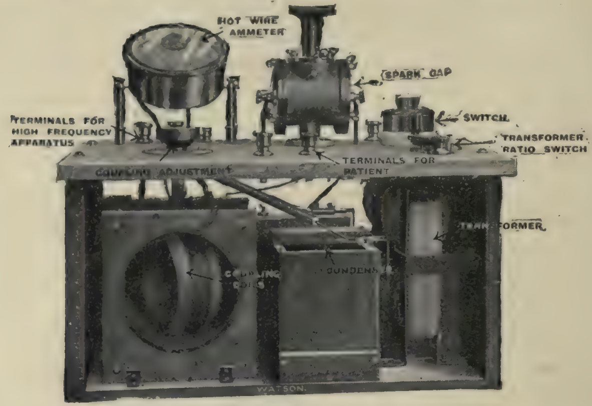

Fig. 9.—Watson's diathermy apparatus.

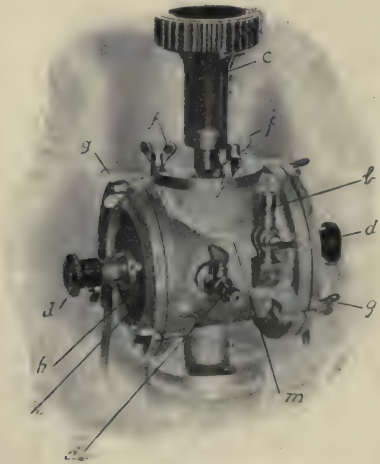

Fig. 10.—Watson's spark gap.

Bridging these two right-angle electrodes is a circular copper disc fitted to the adjustable handle, *c*, in such a way that, on rotating this handle, the copper disc is raised from or lowered on to the two fixed electrodes, thereby opening or closing the gap. It will be found that when treating large body resistances the spark gap requires to be fairly wide, and that when the body resistance between the electrodes is low only a very narrow spark gap is necessary. Two gas-cocks are fitted into the body of the spark gap, the one, A, for receiving the gas supply, and the other, *b*, bent vertically upwards, for allowing the gas to escape when originally filling, or, in those cases in which gas is unobtainable, for the introduction of petrol, acetone, etc., which are quite practicable alternatives.

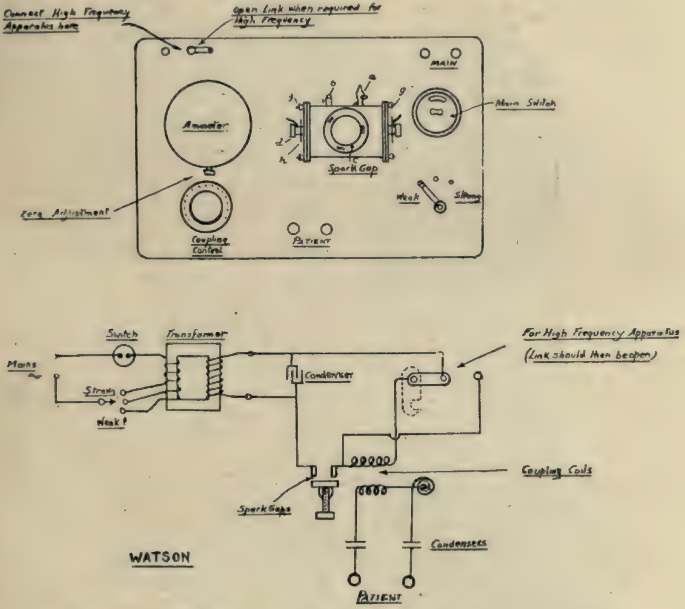

Fig. 11.—Wiring plan of Watson's diathermy apparatus.

Fig. 11 shows a connecting link for the external connection of the special high-frequency apparatus (Fig. 12), for use when very high voltage discharges are required.

The additional apparatus is more suitable for use on the special *diathermy couch* (Fig. 13). It will be noticed that the foot of the couch is provided with selecting switches, by means of which the current can be directed differently as regards polarity to the four metal plates under the couch, without the inconvenience of altering connections.

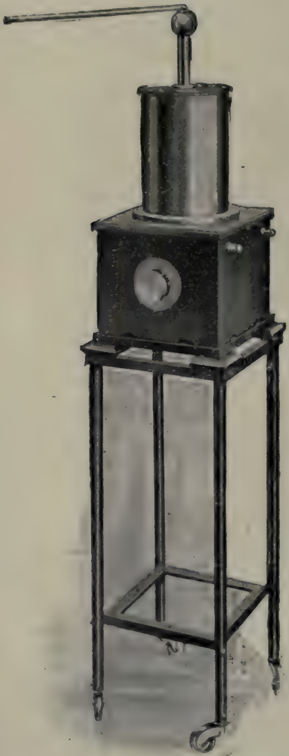

Fig. 12.—Watson's high-frequency attachment to a diathermy machine.

2. **Butt and Co.'s (formerly Siemens') apparatus.** (Fig. 14).—The spark gap is double. Two pairs of silver-lined copper discs are connected in series and placed parallel and opposite to each other. The air gap between each pair of discs is ¼ mm. in width. The spark gap is provided with a safety cover. The condenser is of large capacity, and is made up of sheets of metal separated by mica; it is charged from the alternating-current main via a stationary transformer which raises the voltage of the supply to 2,000.

The current to the patient is taken off a secondary solenoid, and the voltage supplied may be about 1,000 volts or less, according to which of three terminals the electrodes on the patient are connected with. The terminals marked 0 and 2, being connected to the extremities of the secondary solenoid, provide the highest voltage; the terminal marked 1, being an intermediate tapping, supplies a lower voltage (*see* Fig. 14A). The coupling coils also provide further variation of the current by altering the distance between the primary and secondary high-frequency solenoids. When the resistance is high, as in giving hand-to-hand diathermy, the electrodes are connected to terminals 0 and 2; when low, as when applying diathermy to the knee-joint, we connect to terminals 0 and 1.

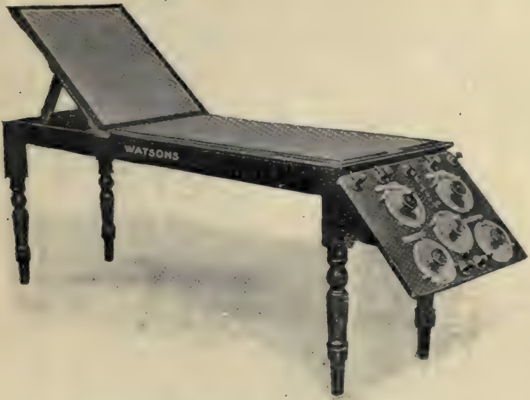

Fig. 13.—Watson's diathermy couch.

3. Schall and Son's apparatus. (a) *Small portable apparatus.* — This apparatus can be wired to work off either alternating or continuous currents, and currents exceeding 2 amp. can be ob-

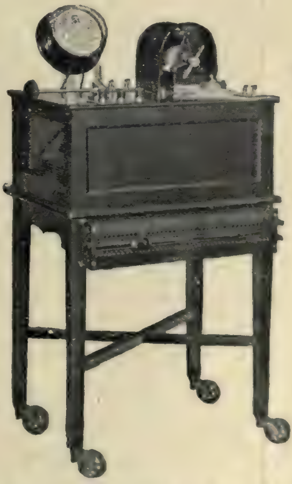

Fig. 14.—Butt and Co.'s (formerly Siemens') diathermy apparatus.

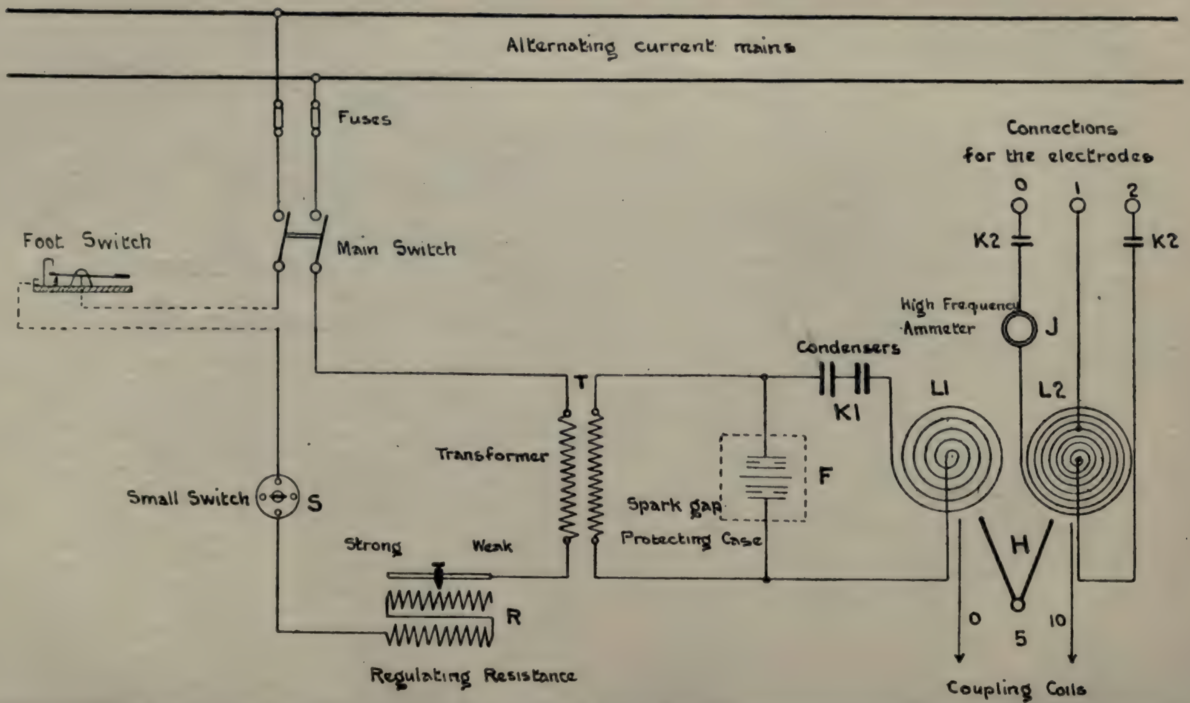

Fig. 14A.—Wiring plan of Butt and Co.'s apparatus for working off an alternating-current supply or two wires of a three-phase supply.

tained from it. Methylated spirit or alcohol is used in the spark gap. The machine can be used for both medical and surgical purposes. My experience with a small portable apparatus in surgical work shows that there is much room for improvement in design. There

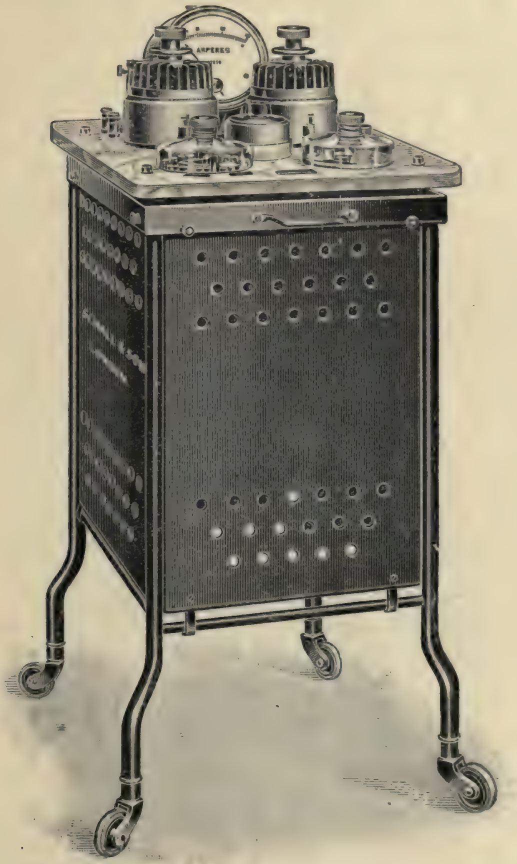

Fig. 15.—Schall and Son's diathermy apparatus.

is urgent need for a good small and reliable portable apparatus for surgical work. The machine should be suitable for attachment to the ordinary lighting mains,

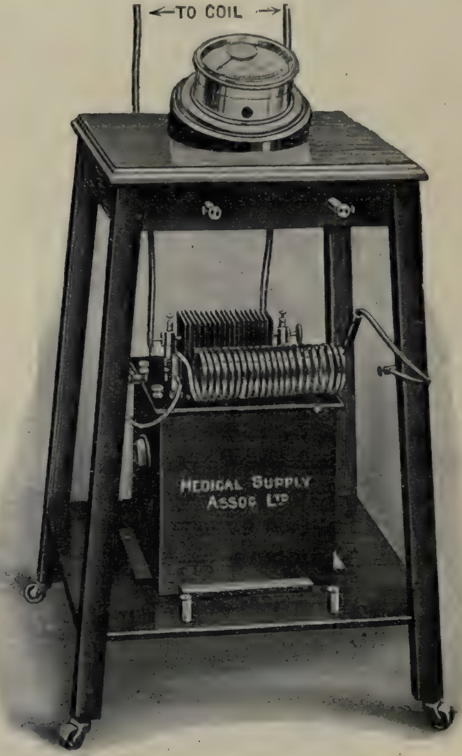

Fig. 16.—Diathermy and high-frequency attachment for working direct from an X-ray coil.

and, if arranged for alternating current, the primary of the static transformer might be conveniently wired to work off either 100 or 200 volts at will. This would necessitate a double-wound primary. For surgical purposes the machine must be regular in action and controlled by a foot switch.

At present, operators have to transport big machines to Nursing Homes, and on account of the large amount of current consumed in the primary of the transformer, special cables capable of carrying the current have to be installed. In cases in which only the continuous current is available, motor transformers are also necessary in order to convert it into an alternating current.

(*b*) *Large universal apparatus.*—This machine has two spark gaps, which may be used either separately or combined. Alcohol vapours are used in the gaps. The hot-wire ammeter registers up to 5 amp., and the current is controlled by means of a variable rheostat and variable transformers. (Fig. 15.)

A diathermy apparatus which can be attached to any X-ray coil outfit at a small cost has been produced by the Medical Supply Association. (Fig. 16.)

CHAPTER IV

PHYSICAL PROPERTIES AND PHYSIOLOGICAL EFFECTS OF DIATHERMIC CURRENTS

Physical Properties

High-frequency currents differ in many ways from the continuous current in regard to their conduction through various media. Metallic conductors, for instance, offer a high resistance to the passage of high-frequency currents. As an example, take the helix of wire or solenoid which joins the two outer coats of the Leyden jars in d'Arsonval's apparatus. The solenoid is usually composed of about twenty turns of thick copper wire. Now, thick copper wire is one of the best conductors of the ordinary continuous current; the resistance of the helix of wire is, in fact, only a very small fraction of an ohm. The solenoid, however, offers an immense resistance to the passage of the high-frequency oscillations, a fact which can be readily demonstrated by approaching a finger-tip between two turns of the wire, when vigorous sparking will occur from one turn to the other via the finger-tip, the current preferring to take the path offered by the finger in spite of its relatively enormous resistance, as compared with the copper wire when the continuous current is being used.

Apropos of this phenomenon, Prof. J. A. Fleming[1] writes: "If the difference of potential between the ends of a conductor is established with great suddenness, the resulting electric flow is less and less determined by what may be the true resistance, and more by the inductance of the conductor. We have a mechanical analogy in the case of impulses or sudden blows given to heavy bodies, which well illustrates how strikingly force phenomena may be altered when for steadily or slowly varying forces we substitute exceedingly brief impulses or blows. If an explosive, such as gun-cotton, is laid on a stone slab in open air and simply ignited, it burns away with comparative slowness, the slab is uninjured, and the evolved gases simply push the air away to make room for themselves. But it is well known that by means of detonators the same explosive can be fired with enormously greater rapidity, and in this case the blow or impulse given to the air is so sudden that it has not time to be pushed away, and its incapability of receiving a finite velocity in an infinitely small time bestows on it an inertia resistance which causes nearly the whole of the effect of the explosion to take effect downwards on the slab, and this last is shattered. The inductance of conductors introduces a series of phenomena which are the electrical analogies of the above mechanical experiment. A conductor of sensible inductance can no more have a current of finite magnitude created in it instantaneously than a body of sensible mass can have a finite velocity instantaneously given to it. In both cases there is an immense resistance to very sudden changes of condition."

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[1] "The Alternating Current Transformer," Vol. I.

Another point of difference between high-frequency currents and the continuous or direct current is that the former are conducted chiefly along the "surface" of metallic conductors, whereas the latter travel equally in the deep and the superficial parts. This peculiarity of high-frequency currents is known as the "skin effect," and in the case of very high frequencies of several million oscillations per second the conducting skin is said to be less than $\frac{1}{100}$ mm. thick. The solenoid of some high-frequency machines is made up of hollow copper wire because, for the reasons given above, hollow tubes conduct high-frequency currents equally as well as solid ones.

In the passage of high-frequency currents through saline fluids, and through the tissues of the body, this "skin effect" is not observed. D'Arsonval found that when this current was passed through a saline solution, the centre of the solution was practically as much heated as the periphery. The study of the passage of these currents in living tissues is somewhat difficult because of the circulating fluids of the body, but we know from practical experience that these currents penetrate the deep tissues.

Physiological Effects

The therapeutic value of heat is well known. We are all familiar with the hot linseed or bread poultice, and the hot-water bottle. Normally we derive our internal heat supply as a result of the combustion of food in the alimentary tract. Previous to the introduction of high-frequency currents artificial heat could only be supplied to the body by conduction or radiation from the outside, the body or part being heated from without inwards. The advent of diathermy now enables us to apply an "internal poultice," and the heating effect takes place right through the tissues, so that the deep-lying structures are heated. The following simple experiment will demonstrate the heating-through effect of the diathermy current. Fill a flat dish made of vulcanite, porcelain or other non-conducting material with egg-albumen. Apply a small pair of disc electrodes to opposite ends of the tray. Turn on the current, weakly at first, and gradually increase the strength. After a time you will notice coagulation of the protein in the centre of the tray, half way between the electrodes. This coagulation will gradually spread from the centre towards the electrodes at either end of the tray. If at the commencement of the experiment a strong current had been turned on, the coagulation would have first appeared immediately under the electrodes.

The heating of living tissues traversed by the current from a diathermy machine gives rise to certain physiological effects. Some of these can be readily studied by simply holding in each hand a pair of cylindrical metal electrodes attached to the two terminals of the apparatus by well-insulated cables. Before the current is turned on, a thermometer may be placed in the mouth or axilla and the temperature noted. The thermometer is then left in position and the switch on the diathermy is turned to the " On " position. The current regulator and spark gap are so adjusted that 400–500 ma. are recorded on the ammeter; usually this is sufficient, but the amount of current that can be borne depends upon the size of the subject's wrists.

At first nothing is felt, but very soon a pleasant sensation of warmth is felt at the wrists. As a rule this heating effect is more marked in the left wrist, because in right-handed people the diameter of the left wrist is smaller than that of the right, and the current density is therefore greater in the wrist having the smaller diameter. It will be found, occasionally, in patients having a very dry skin, that a slight faradic sensation is complained of when the current is first turned on; this can readily be remedied by first moistening the palms of the hands with water. Sometimes the faradic sensation is due to the position of the spark gap, and a slight adjustment of the gap is all that is necessary. A " dirty " spark gap will cause a faradic sensation to be felt. In order to ensure efficient and smooth working, the spark gap must be kept scrupulously clean, and the surfaces of the copper plates should be rubbed smooth with emery paper from time to time.

The sensation of warmth first felt in the wrists gradually increases and slowly spreads up the forearms towards the elbows; the wrists, however, always feel the warmest, and the sensation of heat gradually diminishes as the diameter of the forearm increases. Flexion of the wrists permits a stronger current to be tolerated; the heating effect in this position is very noticeable in the flexor muscles of the forearm. After the sitting has lasted 10–15 minutes, the patient begins to feel warm all over the body, and the pulse-rate usually rises. Sometimes there is a fall of blood-pressure, but the effect both on the pulse-rate and on the blood-pressure depends on various factors—the previous condition of the blood-pressure, and also the condition of the heart, blood-vessels, and kidneys.

Sloan has studied the action of high-frequency current on the general blood-pressure. When patients are treated on the condenser couch, there is at first a tendency to a fall of blood-pressure, owing to the peripheral vaso-dilator action of these currents. In healthy subjects the heart's action becomes more vigorous and checks this fall, the blood-pressure returning quickly to its normal level or even above this. In subjects with a feeble heart, or in those suffering from arterio-sclerosis, a pronounced fall of blood-pressure may be produced owing to the inability of the heart to compensate for peripheral dilatation.

There is no doubt that the diathermy current produces a marked lowering of the general blood-pressure in suitable cases.

The passage of the current causes a general rise of temperature. After a few minutes' treatment the sweat-glands begin to become active and perspiration breaks out. The active circulation set up in the forearms rapidly carries away the heat and distributes heated blood all over the body. If it were not for the active circulation set up in the tissues under the electrodes when giving diathermy treatment, the parts would rapidly become dangerously overheated. For this reason it is important to see that no tight bandages or constricting sleeve bands interfere with the circulation in the limbs. If the temperature at the wrists rises too high, the patient complains of an aching sensation, which gradually becomes intolerable unless the current is reduced. This pain at the wrists can to a large extent be avoided by wrapping the forearms from wrist to elbow in well-moistened saline cloths (10 per cent, NaCl.) of several thicknesses, and using large plate electrodes moulded and fastened to the forearms on top of the cloths; the cylindrical metal hand electrodes being, of course, dispensed with in this case. By this means larger currents can be administered and considerable rises of temperature obtained. The following is a record of personal observations on a patient treated in this manner, i.e. with saline cloths wrapped round the forearms.

CHART OF TEMPERATURE UNDER DIATHERMY

Patient—Male: Weight, 14 st. 8 lb. net; Current 1–1½ amp.
Usually this subject had a subnormal temperature.

Mouth temperature at the outset	97·8°F.
,, ,, after 6 minutes' treatment .	98·4°F.
,, ,, ,, 10 ,, ,, .	98·7°F.
,, ,, ,, 15 ,, ,, .	98·8°F.
,, ,, ,, 20 ,, ,, .	98·9°F.

The patient was then commencing to perspire and the sitting was terminated. The axillary temperature would no doubt have given a still higher reading.

Bergonié[1] records some observations of Réchou in which he raised the temperature by diathermy 4° F. in the axilla, and 1° F. in the rectum.

In vigorous general-diathermic treatment carried out in this manner, patients may complain of faintness, probably due to a rapid fall of blood-pressure caused by the current.

The application of diathermic currents in certain inflammatory and ischæmic conditions which we will discuss later promotes tissue drainage and relieves the congestion, giving marked relief from pain. This is brought about by the oscillations set up by the current; and the flushing of the inflamed parts by the actively circulating heated blood, which causes absorption of the inflammatory products and deposits in the tissues, promotes oxidation and stimulates metabolism.

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[1] *Arch. d'Électricité Méd.*, May 10, 1913.

De Kraft is quoted by Lewis Jones[1] as saying: "Venous congestion, wherever present, is relieved because of the marked activity of the arterial circulation. Anæmia of the splanchnic area ensues. Visceral congestion is relieved. The liver, the intestines, and other organs within the abdominal cavity are made to disgorge the stagnant pools of blood which bathe their structures. When the action of the diathermic current has subsided and the blood-stream returns again to its normal channels, freshly oxygenated arterial blood enters in greater abundance into the previously anæmic and (before the heating) venously congested areas. The parts are placed in a better state of defence against the invasion of toxins and bacterial colonies."

M. Réchou gives some interesting observations[2] on the respiratory changes induced by diathermy applications. Before diathermy the oxygen consumed by the subject in 10 minutes was 2·95 litres. After 30 minutes' treatment less oxygen was consumed and less CO_2 given off. Réchou's table of the experiment is appended. It will be seen that during the treatment the artificial increase of the heat supply resulted in less heat being formed from within.

CHART OF RESPIRATORY EXCHANGES UNDER DIATHERMY

Before treatment	*Beginning of treatment*	*After 30 minutes' treatment*
O_2 consumed in 10 mins. = 2·95 litres.	O_2 = 3·63 litres.	O_2 fell to 2·14 litres.
CO_2 given off in 10 mins. = 2·62 litres.	CO_2 = 3·16 litres.	CO_2 fell to 1·96 litres.

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[1] "Medical Electricity," 7th Edit., p. 339.

[2] Quoted by Bergonié, *Arch. d'Électricité Méd.* March 10–15, p. 15.

Réchou found a considerable amount of acetone in the urine of stout subjects after diathermic applications; this, he says, is possibly due to liquefaction of fat and to the excess in the blood being incompletely used up.

When giving general high-frequency treatment on the condenser couch, d'Arsonval noted that among other physiological effects was an increase of CO_2 output from 17 to 37 litres. There was also an increase of heat production from 79 to 127 litres, and an increase of nitrogen and phosphoric acid in the urine.

Nagelschmidt has found diathermy to have a stimulating effect on cells and glands.

There is no doubt that in elderly people, and in conditions of marasmus and inanition, conditions aptly described by Bergonié as a state of "*misère physiologique*," or hypothermy, the exhibition of diathermy is followed by improvement in appetite and in general health. Digestion improves and weight increases. The treatment has a soothing effect upon the nervous system, and promotes sleep, and a general feeling of well-being is produced in the patient. All authors agree that diathermy has marked analgesic properties in every kind of painful affection. It is to be noted that after diathermic treatment the skin covered by the diathermic pads appears to be less sensitive to applications of the continuous or faradic currents, and patients can tolerate larger intensities of current if ionization immediately follows a diathermic application. This decreased sensibility of the skin may be partly due to the lowered resistance of the hyperæmic tissues, and the moistening of the skin with the diathermic pads. The common opinion held as to the action of general high-frequency given on the auto-condensation couch is that the therapeutic effects are mainly due to heat production, but experiments carried out by Sloan[1] do not appear to support this view. He points out that the resistance in the deeper structures is too low to evolve much heat, and his conclusions, and the results of his experimental work, as set out in Chapter XI. of his work, are of considerable interest.

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[1] "Electrotherapy in Gynæcology," p. 310. 1907.

M. Bergonié has found that in cases of defective alimentation, diathermy, by supplementing the natural heat-production of the body, relieves the strain on the weak digestive system, and replaces to a certain extent the calories usually derived from food. The argument is that patients with defective digestion can afford to take less food while undergoing diathermy treatment, and it is pointed out that a considerable amount of the energy which the organism obtains from food is expended in maintaining the warmth of the body.[1]

Prof. Zimmern[2] quotes Bergonié as saying: "Every time that the general application of diathermy has been adopted with malingering, criminal, marasmatic, feeble or hypothermic subjects, I have seen the temperature rise, and with this an increase of weight, of arterial pressure, and of strength. I have found their alvine motions become regular, their alimentation become less intensive, more easily adjusted and more varied. I have seen those organisms which have been in a state of *misère physiologique* become capable of both physical and intellectual work, of defending themselves better, and above all of having no need of diathermy after the return to the normal condition."

Dr. Albert C. Geyser, in a paper on "The Therapeutic Value of Diathermia,"[3] points out that inflammation is a physiological process, is nature's attempt to cure, and that the principal factor in inflammation is the production of heat. Diathermy currents produce "physiological heat within the tissues," and thereby assist nature to react and cure disease. If used within physiological limits these currents are "vitalizing and constructive." In these papers Geyser expounds the vibration theory of all living cells.

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[1] *Arch. d'Électricité Méd.*, March 10, 1913.

[2] *Med. Press and Circular*, 1914, xcvii. 8, 38.

[3] *New York Med. Journ.*, 1916, ciii. 354–57.

In an interesting paper entitled "A study on the Influence of Electricity on Metabolism,"[1] Matthew Steel, Ph.D., finds that high-frequency treatment on the autocondensation couch increases the elimination of total solids in the urine, and the number and amplitude of the respiratory movements, and has a pronounced effect on the blood-pressure and pulse-rate.

F. de Kraft, in the Report of the Committee on High-Frequency currents,[2] says: "The first effect of the great rapidity of the succeeding groups of oscillations is an intense heating of the surface of the body, and of the blood. This in turn stimulates the great system of vasomotor nerves, resulting in peripheral dilatation of the blood-vessels, and, at the same time, in the stimulation of sweat-glands. It would appear that the sympathetic nervous system is stimulated in a most profound manner." Later,[3] de Kraft gave warning as to the indiscriminate use of high-frequency and diathermy currents, and pointed out certain contra-indications to the use of these forms of treatment. In general diathermy via the limbs, the activity of the sweat-glands is found to vary considerably in different subjects: while some patients perspire only slightly, others break out readily into a profuse perspiration.

The artificial general pyrexia resulting from a diathermy treatment differs from ordinary pyrexia in that it is not produced by toxins circulating in the blood. After cessation of the treatment, the heat-regulating mechanism quickly eliminates the excess of heat, and the temperature returns to the normal. Certain tissues, however, such as the bones of the wrist-joint, which readily become heated in hand-to-hand diathermy, retain their heat for a considerable time, and only give it up slowly to the circulating fluids of the body.

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[1] *Amer. Journ. of Electrotherapeutics and Radiol.*, 1916, xxxiv. 192, 243.

[2] *Ibid.*, Nov., 1916. [3] *Ibid.*, April, 1917.

In concluding this review of the physiological effects of diathermy treatment, it must be pointed out that while the effects appear to be mainly brought about by the heating of the tissues, this is not necessarily the only beneficial action of high-frequency currents.

CHAPTER V

METHODS OF APPLICATION

1. **Diathermy condenser couch.**—This is a method of giving treatment which may be used when it is desired to place the whole body under the influence of high-frequency currents. One method of giving general treatment is by means of large pads on the forearms (p. 27). The high-frequency condenser couch, however, acts on a different principle. The patient is only in direct contact with one pole of the machine, being separated from the opposite pole by a layer of insulating material. In the ordinary high-frequency condenser couch the patient lies fully dressed on insulating cushions underneath which is fixed a large metal plate. One terminal of the machine is connected to the large metal plate, the other terminal is either fixed to a handle or handles on the couch which the patient grasps, or is attached to an electrode which may be applied to any desired part of the body. The metal plate and the body of the patient form the armatures of a condenser system, the intervening insulating cushion acting as the dielectric. The patient is alternately charged and discharged, and the whole body is brought under the influence of the currents. It is a good plan to earth the large metal plate under the cushion. In this form of condenser couch the only appreciable warmth felt by a patient holding the handles of the couch is in the wrists.

An improved form of couch specially designed for use with the diathermy machine is now made. The patient is separated from metal plates by a thin sheet of ebonite. By means of an arrangement sometimes called a "changing box" at the head of the couch, any of the plates may be connected to the high-frequency terminals, and the current can either be given to the whole body or concentrated under special parts. The body may also be directly connected to one terminal of the machine, and an electrode can be placed on a part requiring local treatment. In this case the other cable is brought into connection with one of the plates on the couch under the part it is proposed to treat. Fig. 17 shows a diathermy condenser couch. The method of giving general treatment on this couch is rather different in principle from that on which the ordinary high-frequency condenser couch acts, for the following reason: In the diathermy condenser couch the patient is not directly connected to either pole of the machine. We will assume that one cable is connected to the plate under the right shoulder, and the other cable to the plate under the left hip. Each plate will become positively and negatively charged alternately, and corresponding opposite charges will be "induced" in those parts of the body in contact with the ebonite over the plates. The "induced" charges will change their positive or negative charge synchronously with the plates, and high-frequency currents will oscillate through the body between the right shoulder and the left hip. During treatment the patient must be watched, as in some cases a fall of blood-pressure occurs and faintness is produced. It is also advisable for any metallic substances to be removed, such as keys, coins, hat-pins, etc.; corsets containing metal should also be removed.

Nagelschmidt describes a condenser couch in which the patient is covered with a sheet of insulating rubber upon which is placed a web or net of aluminium. This metal covering is connected to one terminal of the diathermy, machine, the other terminal being attached to a single metal sheet under the couch.

2. **Local treatment.**—We have already noted that the diathermy current does not produce any of the usual phenomena associated with electrical applications; there

is no stimulation of the muscles or nerves, nor are there ionic effects. The probable reasons for these facts have been explained (p. 2). Another important difference is that the skin does not offer a high resistance to the passage of

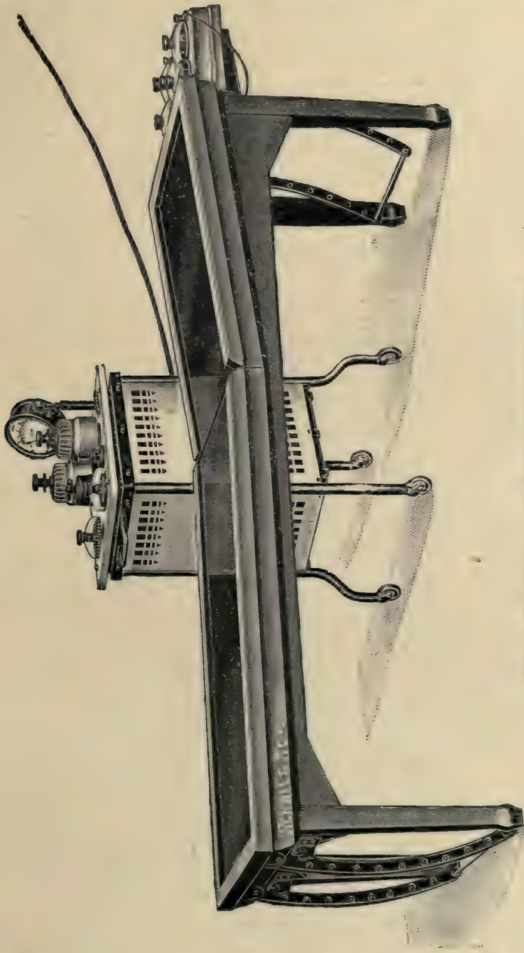

Fig. 17.—Schall and Son's diathermy couch.

high-frequency currents, provided there is good contact between the skin and the electrodes. Except that the bones are said to offer a slightly higher resistance to the passage of the current than the soft parts, the conductivity of the various tissues appears to be practically the same; and the current seems to take the nearest path between the electrodes rather than what might be thought to be the path of least resistance. It is owing to this fact that we are able to localize the chief action of these diathermy currents to the area under treatment. Nagelschmidt, in a paper read before the Electro-Therapeutic Section of the Royal Society of Medicine,[1] thus describes an experiment with a square piece of steak illustrating these points. "Take a square piece of steak, two of the sides parallel to the course of the muscular fibres. You know there is a great difference in the resistance of the longitudinal and the cross sections to an ordinary current. For the high-frequency current, however, we find the resistance is the same for both directions. Take, however, a piece of steak cut in hour-glass shape, you will see that the heating is the greater at that part which has the smallest section, since here the lines of electric force are condensed. If, however, the surface of one of the electrodes is smaller than the smallest section, you may get coagulation under the smaller electrode before you get it at the narrowest part of the muscle. This has a very important practical application. If you take the two handles in your hands you will find the first sensation of heat in your wrists, since the lines of force are closer together there. So you see that the resistance of the human body is not an entrance resistance, or a resistance of structure, but that for high-frequency currents, and especially for diathermy, we have to consider only the mass of tissue and the area of the section traversed by the current."

We will now consider the technical details which it is necessary to be familiar with when treating some local condition by diathermy. The difference between applying diathermy for medical and for surgical purposes is that in the former the object is to raise the temperature of a part to a degree which does not injure its vitality, i.e. within physiological limits, while in the latter these limits are exceeded, and destruction of tissue takes place. Zimmern[1] says: "When the temperature rises to about 113° F. the heat developed becomes painful and can no longer be tolerated." It is quite possible by careless technique to exceed the limit of safety and cause injury to the tissues, and great care is necessary in the choice of suitable pads, in the application of the electrodes, and in regulating the current supplied to the patient. The most important guide to the amount of current that may be safely given in any particular case is the feeling of the patient; the current must be immediately switched off if any discomfort is complained of. With reasonable care diathermy treatment is quite safe. A note of warning must be given as regards the treatment of patients suffering from any trophic changes in the nerves giving rise to anæsthetic areas, or of cases of injury or division of the nerves which supply the part. In these cases the very greatest care is necessary in administering the current, as the patients are unable to appreciate painful stimuli and therefore do not complain of pain or discomfort from overheating.

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[1] *Arch. Röntgen Ray,* Dec., 1910.

Application of electrodes.—The question of the choice and method of application of diathermy electrodes is one of great importance. The electrodes are usually sheets of pliable metal cut to various sizes and shapes (I have found limpet material[2] very convenient and reliable). Provided that they are carefully moulded and shaped to the part to make good contact, they may be applied direct to the moistened skin. Personally, I always employ cloths or other absorbent material well moistened in 5–10 per cent. warm saline solution between the skin of the patient and the electrodes. One to two tablespoonfuls of salt to a pint of water is sufficient. The pads are folded in several thicknesses, for example 8–16 layers of surgical lint, and should be slightly larger in area than the metal plate electrodes with which it is proposed to cover them. When the pads and plates have been placed in position, they must be securely fixed by means of bandages or straps, due care being taken that the circulation in the part is not interfered with. The metal plates must be securely connected by means of well insulated cables to the terminals of the machine.

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[1] *Med. Press and Circ.*, 1910, xviii. 353.

[2] "Limpet" materials may be obtained from the Medical Supply Association, Gray's Inn Road, London, W.C. 1.

Electrodes of naked metal moulded to the part and well supported in position by means of elastic bands are preferred by Bergonié. If covered with a napkin soaked in water they remain cool.

Delherm and Laquerrière suggest the use of a metallic web placed in contact with the skin and covered with a mattress of moistened bibulous tissue.

Zimmern prefers to use radioactive earth or clay, which readily moulds itself to the part, remains moist, and conducts the current well. I have had no personal experience of this method, and it is interesting to note that Turrell says "Whatever pads you use, do not use modelling clay."

American physicians frequently use kaolin pads. The German school uses pad electrodes.

More current can apparently be obtained by the application of bare electrodes to the skin, but in many situations it is not possible to get even contact unless pads are used.

If a superficial heating effect is desired, water should be used without the addition of salt ; by this means, increased electrical resistance is obtained, with consequent superficial heating effect.

We will now assume that diathermy is to be applied to a *knee-joint.* The electrodes may be applied in various ways. As we have seen, the diathermy current takes the shortest path between any given pair of electrodes. It is therefore no use to apply one electrode say to the anterior surface of the knee and another to the anterior surface of the thigh, for by this means only the anterior surface of the joint will be heated. Similarly, if " large " pads are placed one in front and one behind the joint, this does not necessarily mean that the centre of the joint receives efficient heating ; most of the heating effect will probably take place in the tissues on each side of the articulation between the lateral edges of the pads. How, then, is diathermy to be applied efficiently to a knee-joint ? We must arrange the size and position of the pads so that the skin areas covered by the electrodes are exactly opposite one another, and the skin areas separating the pads must be at least as wide as the areas covered by the electrodes· After thoroughly warming up the joint with one electrode in front of the knee and one behind, we may turn off the current and place the electrodes on each side of the knee ; the diathermy current will now pass through from side to side, and in this way thorough heating of the knee-joint is obtained. In regulating the current, it is advisable to commence the séance at zero, and gradually increase it until the patient feels a sensation of warmth. The current regulator is now left in the position reached. Gradually the heating sensation increases. After a time, if necessary, the strength of the current can be increased, the patient being instructed to mention immediately if any discomfort or overheating is experienced, when the switch must be immediately turned off. Sometimes patients may complain of excessive heating at the edges of the pads, and then their thickness or position must be altered. Very often a slight wrinkle or fold in the pad is the cause of trouble from overheating at one spot, or the pad may have become dry and require remoistening with the saline solution. A knee-joint may take anything from one to two amperes, the amount of current depending upon the size of the joint, and also upon the size of the pads used under the electrodes. In medical diathermic applications we must always be guided by the sensations of the patient. Diathermic séances usually last 15–30 minutes, and may be given daily or every other day.

Situation of electrodes.—Emphasis has already been laid on the importance of care in the choice of electrodes and their method of application. When areas having irregular surfaces and angles have to be treated, e.g. the face, special care is needed, and considerable ingenuity is often required in order that firm, even contact may be maintained. The size of electrodes chosen in the treatment of various regions of the body depends upon the size and position of the area that has to be treated in any individual case. The following sizes are convenient to have in readiness, viz. 4 × 3 in., 5 × 3½ in., 6 × 5 in., 8 × 8 in.

Fibrositis of the trapezius (p. 75).—An active electrode of suitable size and shape is placed behind the neck and shoulders over the painful area, and securely fixed in position. The patient reclines on a couch, and the weight of the body assists in ensuring good contact with the electrode. A large indifferent electrode is placed on the front of the upper part of the chest, with a sandbag to retain it in position.

Shoulder.—The active electrode is moulded over the top of the shoulder and deltoid and is retained in position by means of bandages. It is not always easy to fix an electrode firmly in this position. The bandages must not constrict the axilla and interfere with the circulation, or overheating of the tissues will rapidly take place. The indifferent electrode may either be placed on the opposite shoulder or wrapped round the forearm of the same side. An alternative method is to use two small active electrodes, placing one over the front of and one behind the affected joint, and strapping them firmly in position.

Forearms and wrists (*see* p. 27).

Hip.—The best method of heating up the hip is for the patient to recline on the couch with one electrode placed under the gluteal region, and the other over the groin and anterior aspect of the upper part of the thigh, with sandbags on top of the latter to maintain it in position.

Lumbar area (*see* p. 73).

Knee (*see* p. 39).

Foot (*see* p. 50).

Rules to be observed in the local application of diathermy for medical purposes.—1. Always give careful consideration both to the size of the electrodes and to the positions in which to place them.

2. Make sure that the saline pads (when using pads) are thoroughly and evenly moistened, and that no wrinkles or folds are present ; also that no edges or corners of the metallic electrodes overlap the pads and touch the skin of the patient.

3. When treatment is begun, the current regulator must be in the zero position.

4. The spark gap must be in perfect order.

5. Before turning on the current make a final inspection of all connections.

6. Gradually increase the strength of the current, until the patient feels a sensation of warmth, and remember that it takes a little time to heat the tissues. After a few minutes the current will reach its maximum heating effect for that strength, and may, if necessary, be increased.

7. Always be guided by and pay prompt attention to the feelings of a patient. Turn off the current immediately if overheating is complained of, or should the current density be too great at one spot.

8. If anæsthesia is present, do not give diathermy unless absolutely necessary. Great care must be taken in administering diathermy in all trophic conditions of the skin.

Contra-indications to the use of high-frequency currents.—1. Inflammatory conditions associated with walled-in pus.

2. Venous thrombosis.

3. Care is required in applying diathermy in cases of advanced arterio-sclerosis.

4. Some authors do not consider high-frequency applications advisable during menstruation.

5. Diathermy must be avoided in acute hæmorrhagic conditions, e.g. pulmonary hæmorrhage, gastric ulcer, etc.

6. High-frequency currents of big amperage should not be given soon after a meal.

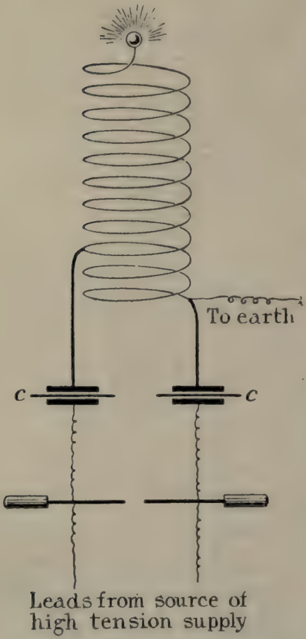

Fig. 18.—Diagram of Oudin's resonator.

High-frequency effluve.—By means of a small apparatus connected to the diathermy machine (Fig. 12) the voltage of the high-frequency current may be raised to a potential sufficient to give strong brush discharges and operate glass vacuum condenser electrodes. The principle employed is that of **Oudin's resonator,** which was designed in 1892. A resonator is made up of a coil of wire wound vertically on a wooden cylinder or frame, and terminates in a knob at the top. One of the condensers of the high-frequency machine is connected to the bottom of this helix of wire, and the other condenser is attached to a coil of wire higher up on the helix, the best point of attachment being found by actual experiment. When properly tuned, a violet brush discharge is given off from the top of the resonator, and this can be led off by an insulated high-frequency cable to the brush or condenser electrode. The bottom of the resonator is usually earthed by attachment to a gas- or water-pipe. When arranged in this manner the coils of wire on the resonator included between the attachments from the two condensers act as the primary high-frequency solenoid; the remaining coils of the resonator, acting by "resonance," enormously increase the voltage of the current. (*See* Fig. 18.)

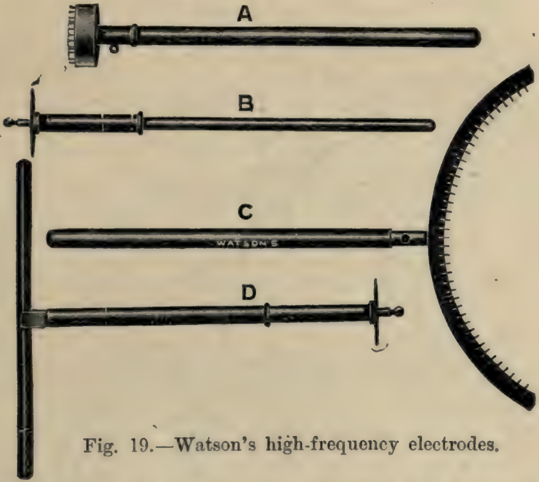

Fig. 19.—Watson's high-frequency electrodes.

The high-frequency effluve is administered to the patient by means of a *multiple-point brush electrode*, such as is seen in Fig. 19, A, which is gradually brought near to the patient, but not too near, or painful sparks will jump from the electrode to the patient.

Glass vacuum electrodes.—These are known as condenser electrodes, because the current flowing to the inner surface of the tube along the wire produces, by electrostatic induction, a corresponding charge on the outer surface of the glass. The electrodes are made in various sizes and shapes to suit different purposes. (Fig. 20.) When approached to the skin they give off a violet brush discharge, and numerous small crackling sparks, and the air within the tube glows with a violet light. In giving the treatment the glass electrode should be first placed on the skin, and the current is then gradually turned on. Loud crackling sparks stream from the glass on to the skin, and a prickly sensation is felt. The electrode is kept in contact with the skin and is moved about over the area requiring treatment, the skin quickly becomes red, and a heating sensation is felt by the patient. A more vigorous stimulation of the skin can be produced by slightly withdrawing the electrode from contact with the skin for a few seconds; this causes a torrent of sparks to jump across the gap. Occasionally the electrodes become overheated and crack, or they may be punctured by a spark; in this case the application must be immediately stopped. Prolonged use of the electrodes may blister the skin.

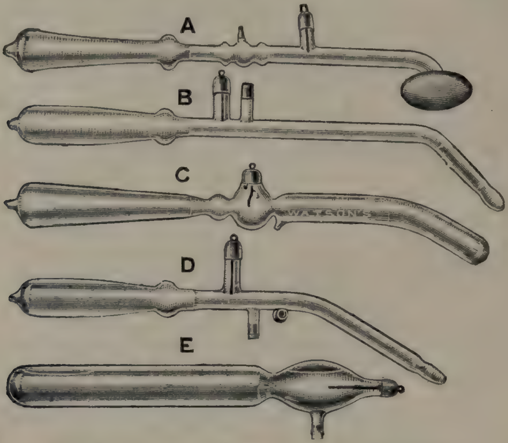

Fig. 20.—Watson's glass vacuum electrodes.

Therapeutic action of the high-frequency effluve and condenser electrode discharges.—These forms of high-frequency application act by stimulation of the skin and the production of erythema. They tend to relieve pain and promote superficial tissue drainage. In addition to the thermal and luminous effects, there is a production of ozone and oxides of nitrogen from decomposition of the atmosphere ; the smell of this gas is quickly noticeable in the air of the room. The formation of the gases may in part account for the germicidal action possessed by these high-frequency discharges. The stimulation produced is of proved value in certain diseases of the skin.

Falling of the hair and alopecia are frequently treated by either the high-frequency effluve or the condenser electrode applied to the scalp. There is no doubt about the value of these applications in alopecia areata.

Chronic eczema, lupus and acne may be benefited as a result of the inflammatory reaction produced by application of the condenser electrodes. Certain septic infections of the sweat-glands and hair-follicles derive benefit, and sometimes sluggish wounds and ulcers may be stimulated into a healthy reaction.

Ozæna and other septic conditions of the nose, mouth, vagina or rectum requiring disinfection can be treated by means of special glass vacuum electrodes.

Blood-pressure.—Rapid stimulation over a large cutaneous area, or stimulation over the spine, will cause the blood-pressure to rise.

PART II.—MEDICAL APPLICATIONS OF DIATHERMY

CHAPTER VI

DISEASES OF THE CIRCULATORY SYSTEM

DIATHERMY currents have a profound effect upon the circulation, and place at our disposal a powerful means of influencing both general and local circulatory disturbances. The effects which it is desired to produce depend upon the particular method of application, i.e. whether general or local diathermy is applied, and whether weak or strong currents are used. In attempting to treat any serious disturbance of the circulatory system by this means, a careful diagnosis of the cause of the trouble must first be made. For example, if vigorous general diathermy is given to a patient with a low blood-pressure and feeble heart, fainting may occur. The condition of the kidneys must be borne in mind, as these may be the cause of hypertension, in which case general-diathermy applications are not likely to be of any practical use. In subjects with normal blood-pressure diathermy does not cause a fall of blood-pressure ; in fact, the increased action of the heart induced by the application may cause a temporary rise. It is well known that auto-toxæmia is a frequent cause of arterial hypertension, and in this connection the danger of indiscriminate use of high-frequency currents is well illustrated by the reply of Dr. Ettie Sayer to a remark by Hale White that " alimentary toxæmia has never been produced experimentally."[1]

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[1] Discussion on Alimentary Toxæmia, Royal Society of Medicine, quoted by de Kraft in a Report of the Committee on High-frequency Currents in America.

" One of the procedures which involve this risk," said Dr. Sayer, " is the attempt to reduce a raised blood-pressure by means of high-frequency currents in cases of chronic auto-intoxication during periods of constipation. An excessive absorption of enterotoxins from the intestines may be set up which will not only send the pressure up, instead of allowing it to come down, but may also produce an acute exacerbation of toxæmia. An old lady whose blood-pressure was 228 mm. Hg suffered from constipation alternating with diarrhœa and various aches and pains. After an aperient had been administered a course of high-frequency was given. All went well for a few days, but then she had to leave town for a week. On her return her pressure was 196. She was asked whether she had had relief that day, and replied, 'Yes, twice.' But the current, which she had previously found agreeable, had only run for four minutes when she felt giddy and thought she was going to faint. She became an ashen colour, her whole body cold and clammy, her pulse irregular, and her blood-pressure had risen to 217. Palpation of the abdomen revealed scybalous masses, which, of course, furnished the cause of the accident. She acknowledged the relief to which she had referred to have been entirely inadequate." De Kraft, who was Chairman of the Committee on High-frequency Currents in America, has had reports of several similar cases.

We will now consider some of the circulatory diseases in which diathermy has proved to be a useful addition to our therapeutic armamentarium. It may be premised that as a general rule it is advisable for patients to rest after diathermic applications.

Angina pectoris.—In this distressing complaint the action of diathermy in relieving arterial spasm is of particular value. A large indifferent electrode is placed over the dorsal spine, and a smaller electrode on the front of the chest, over the base of the heart and cardiac area.

Nagelschmidt has had a very large and successful experience in the treatment of this and other circulatory diseases, and in a paper read before the section of Electro-therapeutics and Radiology, British Medical Association, Birmingham,[1] said : " It is most remarkable to see how patients in a very grave condition recover immediately under the influence of diathermy. In a few seconds or minutes all trouble ceases, no oppression, no pain, no restlessness, no feeling of anguish." He recommends a current of 1,000–1,200 ma. for five minutes or more, according to the effect produced. " In cases of angina pectoris," he adds, " if we do not get a prompt therapeutic effect, we may always suspect an aneurysm or grave myocarditis."

Intermittent claudication.—In this rather curious condition severe pain comes on in one or both legs on walking a certain distance. The pain compels the patient to stop ; after a short interval of rest the pain ceases, but returns on resuming the walk. The condition appears to be due to a defective blood supply to the leg muscles ; in some cases it seems to be associated with calcareous arteries or phlebitis.

Applications of diathermy are a successful means of treating this disease, and the treatment may be supplemented by applications of rhythmically varied galvanic, faradic or sinusoidal currents in the Schnée bath.

Delherm and Laquerrière[2] report a series of cases in which high-frequency treatment has proved very useful.

The **état prescléreux** described by French authors is benefited by diathermy. Nagelschmidt reports a considerable fall of blood-pressure in some cases, and says the action of the currents may last for months or even years after only a few treatments. In other cases prolonged and repeated treatments are necessary.

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[1] *Arch. Röntgen Ray*, Feb., 1912.

[2] *Arch. d'Électricité Méd.*, 1909, xvii, 787.

Dyspnœa on exertion, palpitation and giddiness are relieved, together with any precordial distress.

Cumberbatch has noted "complete relief of symptoms in some cases of **arterio-sclerosis** without lowering of arterial blood-pressure."[1]

Circulatory disturbances of the brain.—A. E. Scherbak[2] reports good results both in organic and in functional cases, and says that a high blood-pressure is usually lowered. Electrodes were placed, one on the upper cervical area, and the other over the mid-dorsal spine, the combined area of the electrodes being 57·5 sq. cm. The intensity of the current was 0·5 to 0·7 amp., and the duration of the séance 5–6 minutes. In cases of severe headache accompanying right-sided hemiparesis, and hemianopsia with atrophic changes in the eye and loss of hearing, twelve to fifteen applications relieved the headache, which was the only troublesome symptom. In a case of cerebral syphilis accompanied by headache, hyperæmia and noises in the ears, the patient was restored to working capacity. It is interesting to note that the treatment caused disappearance of an Argyll-Robertson pupil. The author utters a warning against prolonging the treatment, on account of the marked changes produced in the cerebral circulation, and regards anæmia of the brain, a low blood-pressure and excitement as contra-indications.[3]

Ischæmic conditions. (*a*) *Trench foot.*—During the winter campaign of 1914–15 large numbers of men on the Western Front were invalided by a condition which was called trench frost-bite. The cases varied in severity from simple congestion to actual gangrene. The condition was caused by tired men standing in strained positions for long periods in cold, wet and muddy trenches, the legs being in many cases constricted by tight puttees. The temperature was not necessarily a freezing one, but the men were unable to take exercise or move their limbs about. The affection was usually a painful one, accompanied by stiffness, contracted extensor tendons, œdema and sensory disturbances. I had an opportunity of treating some of these cases of trench foot by diathermy, and the benefit derived was immediate and marked, especially the relief from pain. Thick pads, well saturated in strong saline solution, may be wrapped round the feet, or each foot may be treated separately, one pad being placed on the dorsum and one on the plantar surface; this latter method causes more efficient heating of the toes and front part of the foot. The current is carefully raised to the desired degree, the patient's sensations being the guide. If there are anæsthetic areas, great care must be exercised to avoid burns.

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[1] "Essentials of Medical Electricity," by E. R. Morton and E. P. Cumberbatch, p. 239. 1919.

[2] *Roussky Vratch*, Jan. 2, 1916.

[3] De Kraft, Report of the Committee on High-frequency Currents, *Amer. Journ. of Electrotherapeutics and Radiol.*, 1916.

If sensation is lost, Turrell[1] advises the static breeze and high-frequency glass-condenser electrode. About 0·5 to 0·7 amp. was found to be the right strength of current with pads applied to each foot, the amount of current depending to a large extent upon the size of the ankle-joint; if too much current passes, the patient will complain of aching in the ankle-joints. The condition of the feet in the cases treated steadily improved. Pain, congestion and œdema disappeared, and the feet returned to their natural size. The treatments are best given daily, and should last about fifteen minutes. The sensation of heat in the tissues, and the active circulation set up in the feet and ankles, when diathermy is applied in this manner, last for several hours after the cessation of the treatment. In all cases treated, relief from pain is one of the most striking features. Turrell found the high-frequency vacuum electrode most useful in promoting the absorption of blebs, and in the treatment of ecchymosed surfaces.

[1] *Pract.*, 1916, xcvi. 52.

(*b*) *Chilblains.*—These are frequently greatly benefited by electrical treatment of the local condition. The cause of chilblains is obscure, and many people who suffer from cold hands and feet never have chilblains. Women are more frequently attacked than men, which supports the view that chilblains have some connection with the condition of the blood. Simple mild cases can be cured by hand-to-hand or foot-to-foot diathermy given daily. The method described for the treatment of trench foot is applicable also to chilblains of the feet. More severe cases require that diathermy should be supplemented by treatment with the interrupted or rhythmically varying sinusoidal current. The hands or feet of the patient are placed in a suitable arm- or leg-bath filled with 2 per cent. warm saline solution. Electrodes dipped in the saline solution are placed on each side of the bath, and are connected to the source of supply of the sinusoidal current; a reversing metronome introduced into the circuit serves as a convenient means of interrupting the current. This is a very valuable method of attacking the trouble. If the skin is broken, it must be protected by oil-silk or other material before the limbs are placed in the saline solution. Before the current is turned on, the patient is instructed to place the hands or feet close together, and as far away as possible from the electrodes. The current is then turned on and the metronome started. The patient can regulate the strength to a nicety by gradually separating the affected members and approaching them to the electrodes fixed on each side of the bath. Another method of applying the current is to place the hands or feet in separate baths. The faradic current is said to be equally useful. Various instruments for rhythmically varying the strength of current supplied to the patient can be obtained. Ionization with the constant current is also a useful aid in this disease. Yet another valuable method is treatment with the glass vacuum electrode (*see* p. 44).

(*c*) *Raynaud's disease.*—This condition may be treated on lines similar to those described for trench foot and chilblains.

(*d*) *Volkmann's ischœmic contraction.* — Turrell has reported marked improvement and arrest of the disease in an early case, and in two cases of *local tetanus* immediate relief was obtained.[1]

Sluggish, feeble circulation of the old.—Hand-to-hand diathermy is a great aid and comfort to these patients, especially during the winter months. A small current, 0·2 to 0·4 amp., is all that is necessary, and a sitting of about fifteen minutes' duration is usually long enough. It is not advisable to push the treatment until perspiration is induced. I consider the treatment very valuable. Patients often feel warm and comfortable for the rest of the day, digestion is aided and sleep promoted. Diathermy supplies the heat which the feeble body is unable to supply.

Internal hæmorrhoids. — In cases which do not call for surgical treatment, the introduction of a cylindrical bare metal electrode into the rectum often affords considerable relief. Rectal pain is relieved in a most striking way and hæmorrhage may cease. Hæmorrhoids which do not prolapse, but which give rise to hæmorrhage, pain and irritation, are suitable cases for this treatment. The hæmorrhoids themselves become less troublesome. The technique adopted is quite simple. The patient lies either on the right or the left side, with knees well drawn up and the buttocks near the edge of the couch. A large, well-moistened indifferent electrode may be placed either under the hip or on the abdomen. The rectal electrode is slightly warmed and smeared with a little oil to facilitate its introduction. When all is ready the current is switched on with the regulator at zero. It may now be increased until 1½–2 amp. are registered on the ammeter. The patient gradually begins to feel a sensation of warmth in the rectum. The treatment should occupy from five to ten minutes, and may be given either every other day, or daily if necessary. At the termination of the sitting the current is turned off and the rectal electrode is left in position for a few seconds in order to allow it to cool; this is advisable because if the electrode is immediately withdrawn, it will be found unpleasantly hot for the sensitive anal orifice as this grips the distal end of the metal. Turrell records a case of acutely inflamed internal hæmorrhoids in which the pain was completely removed, and in an interval of fourteen months which had elapsed since the treatment there had been no recurrence of the trouble. He also mentions a case of very profuse hæmorrhage from internal hæmorrhoids, where similar treatment had been followed by an equally long period of freedom from hæmorrhage.[1]

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[1] *Proc. Roy. Soc. Med.*, Jan., 1917, p. 43.

Inflamed and congested prostate.—This condition may be treated with benefit by means of the rectal diathermy electrode on the lines indicated in the preceding paragraph. For such cases the static wave current has also been found useful by some observers.

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[1] Discussion on "The Electrolysis Treatment of Hæmorrhoids," by J. Curtis Webb, Roy. Soc. Med., Electro-Therapeutic Sect., May, 1914.

CHAPTER VII

DISEASES OF THE NERVOUS SYSTEM

Acute anterior poliomyelitis (infantile paralysis).—This is an acute disease due to a toxic or microbic infection which suddenly attacks the ganglion cells in the anterior cornua of the spinal cord. Most of us have in the past been taught either that all the motor cells supplying a muscle are destroyed, and recovery is therefore impossible, or that if the cells are not destroyed the muscle will recover by itself and treatment is practically unnecessary. This is a most pernicious doctrine, and has led to lamentable neglect in the treatment of this terrible disease. We know that, because the motor cells supplying a single muscle are not confined to one single spot in the cord, but arise from a scattered nucleus and derive motor fibres from several spinal roots,[1] the focus of the disease in the anterior cornua may totally destroy some of the nerve cells supplying a muscle, injure others, and yet leave some cells in the nucleus uninjured. Sherrington[2] says: "The position of the nerve cells sending motor fibres to any one skeletal muscle is a scattered one, extending throughout the whole length of the spinal segments innervating that muscle; in the limb regions many muscles receive their motor fibres from as many as three consecutive spinal roots, and the bodies of the nerve cells innervating those must, therefore, inside the cord, extend through the length of three whole segments of the cord as a continuous columnar group, and in each transverse level of the cord these cells must lie commingled with nerve cells innervating many other muscles."

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[1] Saberton, "The Nerve Plexuses of Troglodytes Niger," in "Studies in Anatomy," Manchester University.

[2] *Med.-Chir. Trans.*, lxxxii. 456.

In connection with the testing of the electrical reactions in these cases, I wish to lay great stress on the misleading data, sensory, mechanical and electrical, derived from the examination of a cold and cyanosed limb. The examination should be conducted in a warm room, and the limb to be examined should have been previously warmed. This can be done most effectively and conveniently by diathermy. The effect of any subsequent electrical or mechanical treatment is also considerably enhanced by this preliminary warming of the limb, apart from the beneficial effect produced by the high-frequency current itself in stimulating the metabolic processes, and in promoting tissue drainage. If diathermy is not available, some other means of warming the part must be employed.

Various degrees of injury are met with in muscles attacked by infantile paralysis. In the worst cases no electrical response can be obtained to any form of current; other cases show evidence of reaction of degeneration, and in the mildest cases we have simply a weak response of the wasted muscles to faradic and galvanic stimulation. As regards electrical treatment, the secret of success in any particular case is perseverance; the cases are often very discouraging, and one is inclined to give up treatment, thinking that no good is being done. Even in the most hopeless cases some benefit is derived, in that the nutrition and growth of the limb is better than it would have been without treatment; and the deformities which arise from the unopposed action of the healthy-muscle groups are not so severe as they would otherwise have been; in fact, judicious and persevering treatment will frequently prevent deformities from taking place. Very often muscle that appears to be completely paralysed will be found to contain a few healthy fibres, which, instead of wasting and atrophying from disuse, can be kept in a healthy and vigorous condition, and may ultimately develop some voluntary power.

Treatment.—The limb must always be kept as warm as possible by suitable clothing, and electrical treatment should be given daily. After a preliminary treatment with diathermy, and careful testing of the affected limb or limbs in the manner described by Bergonié,[1] the best type of current to suit the case is decided upon. A description of the methods adopted for the testing of electrical reactions is beyond the scope of this book. One of the best forms of treatment is the application of a rhythmically varying or pulsating sinusoidal current, which can be conveniently given in the form of a limb-bath or baths. Another useful method is the galvanic current, interrupted and reversed by means of a metronome. In addition, daily massage and certain muscle exercises are necessary, and the patient should be encouraged to attempt voluntary movements for a few minutes each day. Fatigue of the affected muscles must be avoided. The correction of any deformity, and the placing of the paralysed muscles in a position of rest, are all-important points which must be carefully attended to. Treatment must be persisted in and maintained for months or even years. Cases of infantile paralysis that have been neglected frequently improve under electrical treatment carried out on the lines indicated above, and no case should be considered hopeless. Electrical treatment may be commenced about six or eight weeks from the onset.

Peripheral nerve injuries.—The remarks already made concerning infantile paralysis and the misleading data obtained from the examination of cold and cyanosed limbs apply equally to cases of peripheral nerve injury. A paper by Burrows and Carter[2] strongly insists upon the necessity for preliminary warming of the part. In applying diathermy we must be careful, when the injuries involve the posterior nerve roots or columns of the cord, with consequent loss of appreciation of afferent stimuli, not to damage the tissues by overheating. Diathermy is a most valuable aid in maintaining and improving the nutrition of a limb or part suffering from division of a nerve or from injury to its nerve supply, and is therefore an important corollary of other methods of treatment.

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[1] *Journ. Méd. Franç.*, 1911, v. 151–58.

[2] "Preliminary Note on Investigations upon one thousand consecutive cases of Peripheral Nerve Injury," *Brit. Med. Journ.*, 1918, ii. 535.

Sciatica.—This painful and troublesome affection is frequently a sequela of lumbago or fibrositis. The inflammation appears to spread to the sheath of the nerve and set up a perineuritis. Before treating a case of this disease by any electrical method, it is necessary first to make quite sure of the diagnosis. Many of us have seen cases diagnosed as sciatica which are really cases of neuralgia, and not true sciatica. The pain may be due to pressure upon the nerve by a new growth, or be a referred pain from hæmorrhoids, anal fissure or affections of the prostate. The pressure of a pregnant uterus frequently gives rise to pain down the sciatic nerve. I remember a case in which a diagnosis of (?) hysteria or (?) sciatica was given, and in which the true cause, as revealed by an X-ray examination, was caries of the lumbar spine. Sciatic pain may be due to arthritis of the hip-joint. Here again an X-ray examination is useful. It is surprising how frequently and readily a diagnosis is given without any effort being made to discover the real cause of the trouble.

Having made our diagnosis, the *treatment* will depend upon the stage of the disease. In the acute stage complete rest in bed is essential, and active treatment is contraindicated. Speaking generally, I have found diathermy of great value in relieving the pain of sciatica. The method I usually employ is as follows: A large well-moistened saline pad is placed under the buttock and the patient lies on it. The other electrode is placed over the inguinal canal and upper part of the thigh; in some cases it is wrapped round the leg below the knee-joint. The strength of the current is gradually increased until the safe maximum is reached, and this is allowed to pass for 20–30 minutes.

In cases giving a history of fibrositis attacking the lumbar muscles which has been followed by sciatica, and in which there is reason to suspect a perineuritis of the cords of the lumbar plexus, one pad is placed under the lumbo-sacral area instead of under the buttock, and the other pad over the lower part of the abdomen. H. Bordier of Lyons[1] discusses the value of this treatment in improving the coldness of the limbs which is associated with cases of peripheral neuritis (sciatica), infantile paralysis, and progressive muscular atrophy. In the treatment of sciatica he uses a lumbar pad, and in the place of a second pad a roller electrode is applied with firm pressure along the course of the nerve. The electrode is kept cool by dipping it in water from time to time. Bordier employs a current of 500–800 ma., and a séance lasts 10–15 minutes. The sensation of heat remains in the limb after the treatment. In suitable cases this treatment is followed by rhythmical galvano-faradization to atrophied muscular groups.

Another method of giving diathermy in cases of sciatica is to apply a small, active, well-moistened and padded disc-shaped electrode, 1½ in. in diameter, with firm pressure to the tender areas or spots along the course of the nerve. A current of ½–1 amp. is passed for a few minutes so as to heat the nerve without injuring the skin. Cumberbatch has found this method successful in some cases in which all other treatments have failed to give relief.[2] Nagelschmidt also reports success by this method of treatment.

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[1] "Efficacité de la diathermie dans les algidités, des neurites et poliomyélites," *Arch. d'Élec. Méd.*, 1914, xxiv. 645.

[2] *Op. cit.*, pp. 298, 309.

In addition, he applies the high-frequency effluve from a special electrode made of thick glass and filled with graphite. This is applied with firm pressure and cooled at intervals.

It is frequently advisable to combine diathermy treatment with *ionization.* In this case, after allowing the high-frequency current to run for about fifteen minutes, the electrodes are left in position, the cables are disconnected from the diathermy machine and attached to the ionization board. The electrode under the loin, buttock or thigh should be made the negative one; chlorine ions are thus driven into the tissues and may prove useful in cases associated with adhesions. It will be remembered that in treating cases by cataphoresis it is essential to increase the current density very slowly to the desired strength, and as slowly diminish it at the end of the treatment. This is especially important when attempting treatment of an inflamed nerve or nerve sheath. If pain is made worse by cataphoresis, this treatment is contra-indicated for the time being. Salicylic ions may be used with advantage in some cases instead of the chlorine ions. I have found this combined treatment by diathermy and ionization of great value in many other conditions besides neuritis. Ionization, to be of any practical service, must be administered for at least 20–30 minutes. Applications of the high-frequency effluve are often useful after either diathermy or ionization.

When the disease is subsiding, treatment by means of the rhythmic sinusoidal bath may be given, provided the patient feels comfortable in the bath and the pain is not made worse.

The question as to when it is safe to begin massage and passive movements is a difficult one to decide. There is no doubt that these forms of treatment must be avoided in the early, acute stage of the disease. Turrell, in opening a discussion at the Royal Society of Medicine on "The

Treatment of War Injuries by Electrical Methods" (Nov. 17, 1916), said: "In relieving the pain of sciatica, neuritis, lumbago, and many like conditions, diathermy is of the greatest value. In dealing with sciatica I have practically abandoned all other methods of physical treatment; early cases are cured quickly, some of old standing require much perseverance and patience, and occasionally one comes across a case which shows no improvement. I believe if sciatica will not yield to diathermy, no other electrical treatment will benefit it, unless perhaps radiotherapy."

When adhesions once form, the condition of the patient is often one of misery. The static wave current may prove useful in some of these cases, but frequently no electrical treatment is of any avail, and the patient gradually becomes worn out with the more or less constant pain. The question of the possibility of breaking down the adhesions by massage and passive movements has to be considered in these cases. Failing this, surgical measures may be called for. As regards sciatic pain, I have been able to relieve some obstinate cases by administering massive filtered X-ray doses along the course of the nerve.

Brachial neuritis.—This is an affection which one is frequently called upon to treat. Here, again, as in sciatica, one must first of all make quite sure of the diagnosis. The pain may be neuralgic in character and due to fibrositis in the cervical muscles. Aneurysm and new growth must be excluded, and in the case of pain radiating down the left arm the possibility of angina pectoris being a cause must be borne in mind. I have seen several cases diagnosed as simple brachial neuritis in which a new growth involving the cervical vertebræ, or cervical caries, has been the cause of the trouble. An X-ray examination is frequently of great value in clearing up the diagnosis of some of these cases. Dental or other possible sources of septic infection must also be looked for. The pain of a genuine case of brachial neuritis is often most severe. Movement of the arm is impossible on account of the intense pain. There may be swelling of the arm and hand, the skin is frequently exquisitely tender to touch (hyperæsthesia) and the limb feels cold. An attack of brachial neuritis may come on quite suddenly without any warning. In these acute cases complete rest and warmth are, of course, essential, and active forms of treatment are contra-indicated. Gentle hand-to-hand diathermy treatment may be given without disturbing the patient, and may be of great comfort. The question of treatment by drugs, etc., must, of course, be left to the physician. In less acute cases, instead of the whole of the skin of the affected member being painful, indicating irritation of the conducting sensory nerve fibres of the nerve trunk itself, definite tender spots can be elicited in the region of the nerve trunks. These tender spots or areas probably indicate that the inflammation involves the nerve sheaths or interstitial tissues, the pain being due to irritation of the nervi nervorum. Cumberbatch[1] suggests the following convenient means of mapping out the tender areas: "The tender area can be effectively localized by means of the faradic current. It is essential that a coil which does not produce painful stimulation of the skin be used. An active electrode covered in a chamois-leather-covered button, ½-in. in diameter, is soaked in saline and stroked over the skin in the region of the pain. Directly a tender spot is reached the patient gives evidence of it. In this way the tender areas can be mapped out."

While considering the subject of neuritis and perineuritis, I wish to touch upon the use and abuse of massage. In my opinion too much liberty is frequently allowed masseurs and masseuses in the treatment of patients handed over to their care. There are, of course, many physicians and surgeons who write down explicit instructions as to the exact form of massage and passive movements they wish a patient to have, and we have many excellent masseurs and masseuses who properly carry out these instructions. At the same time, one frequently comes across cases in which this ideal does not exist, and the unfortunate patient is simply handed over to the tender mercies of some muscular exponent of the art of massage, whose one idea is the creation of "trauma." In some cases, in which there is not much the matter with the patient, little harm is done, and I have known patients who estimate the skill of the operator by the amount of bruising they receive; the more black and blue they are made the better they like it. On the other hand, serious harm may result from unbridled massage, and this is particularly true in cases of neuritis. In the most acute stages of the disease massage is contra-indicated, and it is not an easy question for the physician to decide the stage at which careful, gentle massage may be safely commenced. I have known many cases of neuritis in which massage and passive movements have been persisted in for months, in spite of the condition failing to improve and of the increased suffering of the patient caused by the treatment. Also, it is quite a simple matter, if you give an ignorant masseur or masseuse a free hand, to convert a case of fibrositis into one of neuritis with adhesions.

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[1] *Op. cit.*, p. 297.

As regards the general electrical treatment of brachial neuritis, this may be carried out on the lines suggested in connection with sciatica (p. 57). Some cases of sciatica and brachial neuritis may be followed by trophic changes and atrophy, and adhesions may form round the joints, causing limitation of movement. The treatment of these cases is most difficult. Diathermic applications to the affected joints, followed by X-ray therapy, may be of benefit and help to cause absorption of the periarticular adhesions. In addition, of course, massage and careful passive movements must be persevered in.

Neuralgias.—The term neuralgia is one which is rather loosely used. Its use should be confined to those cases in which there is no actual inflammation in the nerve itself, the pain felt along its course being a "referred" pain from disease situated elsewhere. For example, trigeminal neuralgia is frequently caused by the irritation of a carious tooth, headache may result from digestive disturbance or eyestrain. Cutaneous tenderness, again, is frequently associated with referred pain. The subject is intensely interesting and of high practical importance, and Head's work upon it is of high value as an aid in the diagnosis of disease. In all forms of neuralgia the importance of a correct diagnosis must be emphasized, and great care must be taken to discover the exciting cause of the pain before attempting to deal with the local condition.

Trigeminal neuralgia.—The treatment I have found most serviceable is the application of a large pad well moistened with a 5 per cent. solution of sodium chloride or of sodium salicylate to the affected side of the face. A large indifferent pad soaked in saline solution is either placed on the front of the chest on the same side or is wrapped round the shoulder of the same side. The pads are connected to the terminals of the diathermy machine, and a mild current is allowed to run for about ten minutes. It will be noticed that the position in which the diathermy electrodes are placed is contrary to the usual practice of placing them one on each side of the part undergoing treatment. The reason is twofold: in the first place, it is only necessary to obtain a superficial heating effect in this affection; and, secondly, it is not advisable to place the pads on either side of the head, because the diathermy treatment is immediately followed by ionization without disturbing the position of the pads, and a continuous current passed through the head with the pads in this position is liable to cause faintness. In the latter treatment the face electrode is made the negative one, and the current is very slowly and carefully increased until the desired strength is reached. The ionization should last 20–30 minutes, and the same care must be taken in reducing the current as in increasing it. Treatment must be persevered in, and is given either daily or on alternate days, depending upon the toleration by the skin of the ionization. The diathermy may be given every day without causing harm to the skin. By this method of treatment I have been able to relieve the severe paroxysms which occur in cases of tic douloureux. Heinrich Wolf[1] speaks of the value of diathermy in trifacial neuralgia. Pain involving the fifth nerve may in some cases be due to an actual neuritis, or perineuritis, of the nerve itself. The treatment described above is also applicable to these cases. Leduc, Professor in the School of Medicine at Nantes, a pioneer in the subject of ionic treatment, reports very favourably as to the use both of the salicylic and of the quinine ion in trigeminal and other forms of neuralgia.[2] Lewis Jones also reports a series of good results following the use of these ions, and gives the following abstract of a case reported cured by Leduc with a single application of the ions of quinine.[3] " A female aged 68 years, previously healthy, developed, after exposure to cold, an acute attack of convulsive tic. The pain, which was constant but subject to very frequent exacerbations, was limited to the area of distribution of the submaxillary branch of the left trigeminal nerve. The paroxysms were irregular, set up by a multitude of causes, mental and physical, and more especially by cold. Four years prior to undergoing electrical treatment she was unable to handle anything cold, much less take a cool drink, without experiencing an immediate exacerbation. Hyperæsthesia of the skin was so marked that the slight variation of temperature caused by the opening of a window was sufficient to provoke a paroxysm. Her rest at night was greatly disturbed. She had tried all kinds of medicaments in large doses without experiencing any relief. Every tooth, although sound, on the affected side was sacrificed, but without effect. On September 20, 1902, the nerve was divided, after which the attacks ceased for four days, only to recur with the same frequency and intensity. In March, 1903, a resection of the alveolar border of the lower jaw proved equally ineffective. On February 25, 1904, when she consulted Leduc, her condition was as bad as could be. The introduction of salicylic ions was first tried, and twelve applications were made, but owing to her great distress the sessions had to be cut short and a current of too low a strength employed. This treatment afforded her some relief, and the frequency and intensity of the paroxysms were reduced, whilst the period of sleep was extended. On June 3, ionization with bichloride of quinine in 1 per cent. solution was applied, with a current gradually raised to 20 ma. for 30 minutes, and gave rise to an œdematous redness of the skin, but resulted in marked diminution of the pain and the number of the attacks, as well as in an increase of sleep. The improvement was even more marked on the two following days. On June 5th she had two small reminders ; these were the last. On June 6th the parts were much discoloured and desquamating ; hyperæsthesia very much reduced. A second application was made by way of precaution, and since then she required no further treatment, being absolutely free from pain."

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[1] *Med. Rec., New York*, 1916, xc. 1152–54.

[2] " Electric Ions and their Use in Medicine," p. 70. 1919.

[3] " Medical Electricity," 6th Edit., p. 413. The original report of the case will be found in the *Arch. d'Élec. Méd.*, 1904, xii. 683–94.

Some forms of neuralgia due to referred pain are benefited by treatment with induction-coil currents on the principle of counter-irritation. The application of faradic currents by means of a wire brush will produce strong counter-irritation. Many other forms of neuralgia can be relieved by diathermy only, or diathermy followed by ionization or faradism. Great occipital neuralgia, intercostal neuralgia, sacral backache and ovarian neuralgia in women are typical neuralgias in which electrical treatment is frequently of great value. Nagelschmidt has found diathermy useful in many cases of ovarian neuralgia, in the pains associated with perimetritis and parametritis, and in the pains of tabes.

Dysmenorrhœa.—In purely functional cases, Sloan[1] has found general treatment on the high-frequency condenser couch the best form of treatment, the physical health is improved and nerve tone increased ; or where the illness is visceral in origin he advises dorso-abdominal faradization. Other forms of dysmenorrhœa require different modes of electrical treatment, for details of which the reader must be referred to the above author's work. Turrell[2] says that diathermy will "give immediate and lasting relief in the most acute cases of dysmenorrhœa."

Coccygodynia.—Diathermy applied by means of the rectal electrode with an indifferent pad over the sacrococcygeal area will be found a valuable mode of treatment for this troublesome complaint. A current of 1–2 amp. may be used, the amount of current that can be comfortably borne depending upon the size of the indifferent electrode. The rectum itself will tolerate 2 or more amp. without the patient experiencing any sensation beyond that of mild heat. For details as to the application of the rectal electrode, *see* p. 52.

Chorea.—Diathermy is reported to be valuable in many cases of this affection.

Paralysis agitans is sometimes treated with high-frequency currents. Donner and Mass[3] report the cure of a case by auto-conduction currents. I have had very little personal experience of the effect of high-frequency currents in this disease.

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[1] "Electrotherapy in Gynæcology," p. 310. 1917.

[2] *Pract.*, 1916, xcvi. 54.

[3] *Ann. d'Électrobiol.*, 1905, p. 620.

Insomnia and neurasthenia.—When associated with high blood-pressure, general-diathermy treatment, either on the condensation couch or by means of hand-to-hand diathermy, is valuable. The treatment has a soothing effect on the nervous system. If the blood-pressure is low the static head breeze is a useful form of treatment. These forms of treatment are not, of course, advocated for the treatment of insomnia resulting from pain or other active causes. Sloan says that he knows of no surer remedy for insomnia than faradization of the brain.[1]

Neurasthenia.—Diathermy treatment, either on the condenser couch or hand-to-hand, is of value as an aid to other methods of treatment. Sleep is promoted, digestion improves, and weight increases. During the treatment the patient should be quietly encouraged by a sympathetic and judicious optimism, and a watch should be kept on the blood-pressure. Neurasthenia is frequently accompanied by severe insomnia. I remember two cases which were incorrectly diagnosed as simple cases of neurasthenia with insomnia. Both patients committed suicide. If genuine sleeplessness is a prominent symptom, and a patient is obviously worn out and exhausted, the possibility of suicide must be borne in mind; the patients must not be treated as simple neurasthenics. W. F. Baker[2] applies high-frequency currents to the spine in cases of hypochondriasis, neurasthenia and traumatic neurosis.

Progressive muscular atrophy.—This affection is due to chronic disease of the ganglion cells in the anterior cornua of the spinal cord. Speaking generally, the prognosis as regards benefit from electrical treatment is not hopeful. Notwithstanding, we undoubtedly see, from time to time, cases in which the disease appears to have been arrested; and personal experience teaches that the disease is not so hopeless as one was led as a student to believe. Whether its progress in the anterior cornua is actually modified by treatment, it is difficult to say. In patients in whom the disease begins in one of the upper limbs, I have been in the habit of giving simple hand-to-hand diathermy treatment on alternate days, followed by stimulation of wasted interossei or other muscles by the form of electrical stimulation which proves most suitable in any particular case. If fibrillary tremors are present in a muscle, it is not, I think, advisable artificially to stimulate its fibres to contract, as they are already overworked. It is not possible to stimulate the healthy fibres of a muscle without at the same time stimulating the degenerating twitching fibres. The above treatment should be combined with massage and suitable exercises to the degenerated muscles. I have seen one case in which the progress of the disease appears to have been arrested, and definite improvement has occurred in the wasted muscles of the thenar and hypothenar eminences, and also in the interossei of the right hand. This patient was also having injections and general treatment from the physician in charge of the case during the time he was under my care. Erb advises treatment of the spinal cord by the continuous current, especially of the cervical enlargement, and says he has seen symptoms arrested. Duchenne[1] reports arrest of the disease in an advanced case by means of treatment with the induction coil. In this affection the electrical reactions vary considerably in different cases, owing to the presence of healthy and degenerated fibres in the muscles at the same time. In some forms of the disease there is no evidence of reaction of degeneration, but simply a gradually diminishing response to both faradic and galvanic stimulation.

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[1] *Glasgow Med. Journ.*, Aug., 1901, and "Electrotherapy in Gynæcology," p. 108.

[2] "High-Frequency Currents in Neurosis."

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[1] "De l'Électrisation localisée," 3rd edit. 1871.

Bordier[1] speaks of the value of diathermy as a means of raising the temperature of a cold limb in lesions of the lower neurone. He has found this form of treatment useful in progressive muscular atrophy, and reports a case of this disease. The patient was 31 years of age, and both arms were affected, the hands and forearms being as cold as ice. A large indifferent electrode was placed over the dorsal region, and a roller electrode was used for twenty minutes on both limbs. After 15 séances the natural warmth of the arms and hands returned, and remained up to the following winter, when a further series of eight séances was given. The diathermy treatment was combined with X-ray irradiation of the spine. Bordier gives the following measurements of the deltoid and biceps before treatment was commenced and rather more than one year later:—

	Nov., 1910.		*A year later.*	
	Right.	Left.	Right.	Left.
Deltoid	26 cent.	24·5 cent.	34·5 cent.	28·5 cent.
Biceps (Middle)	23 cent.	22 cent.	30 cent.	25·5 cent.

Specimens of the patient's writing are reproduced. Before treatment he was quite unable to hold a pen, but by March 11th, 1912, he was able to write legibly with well-formed letters. Three years after the initiation of diathermy treatment the hands remained warm.

Disseminated sclerosis.—Bergonié and Réchou[2] mention the case of a patient 45 years of age presenting the signs of *sclérose en plaques*. The case was treated by diathermy, large plates being placed on the abdomen and lumbar spine and a current of 3 amp. passed. The gastric crises which were present in this case disappeared after the first application. Applications were given for five minutes with one day's interval, considerable relief being felt. The patient, who previously was only able to micturate once a day with great difficulty, after the third sitting could do so easily several times a day. I have had no personal experience of diathermy in the treatment of this disease, but having had one case of disseminated sclerosis which I treated with heavily filtered X-rays applied to the cervical and lumbar enlargements, and in which the disease appeared to have been arrested, I would suggest diathermic applications previous to and combined with X-ray therapy as worthy of trial.

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[1] *Loc. cit.*

[2] "Rapport au Congrès de l'Assoc. Franç. pour l'Avancement des Sci., Sec. d'Élec. Méd., Août, 1911," *Arch. d'Élec. Méd.*

Pruritus.—Pruritus ani or vulvæ may sometimes be relieved by the high-frequency effluve or by application of the glass vacuum electrode to the affected parts. I have found, however, that the great majority of sufferers from this troublesome complaint obtain complete relief from a third or half Sabouraud B-dose of unfiltered X-rays administered once a week. A total of three or four of these fractional doses is usually sufficient. Patients with no apparent local cause, such as hæmorrhoids or erythema, for the irritation, are often more difficult to relieve than patients with some obvious source of irritation. Some cases may be successfully treated with the static breeze, and ionization with iodine ions is also reported as a useful method of treatment. It must be borne in mind that pruritus ani appears in some cases to be due to the condition known as dyschezia, i.e. inability to empty a loaded rectum. A bismuth-meal examination will determine whether such a condition is present.

Headache.—If associated with high blood-pressure, headache may sometimes be relieved by general diathermy, either on the condenser couch or applied by means of pads wrapped round each forearm. In some cases the blood-pressure is not reduced by diathermy. The static breeze applied to the head, the body being positively charged, is used in cases of functional headache associated with a low blood-pressure. Wilfred Harris[1] has found the neuralgic type of headache resulting from excitement or nervous overstrain relieved by faradism applied by means of soft circular pad electrodes, one on each temple, or one at the root of the nose and the other at the back of the head, below the occipital protuberance. I have found this method of treatment useful in some cases.

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[1] "Electrical Treatment," 3rd Edit. 1919.

Metatarsalgia.—Cumberbatch[1] has seen good results in two cases of metatarsalgia follow the heating-through of the feet by diathermy. One patient on whom surgical operation had been repeated, without lasting benefit, improved so much that he was able, after a course of treatment, to walk long distances without pain.

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[1] *Op. cit.*, p. 292.

CHAPTER VIII

FIBROSITIS—SCARS AND ADHESIONS—DISEASES OF JOINTS

FIBROSITIS

THIS term has been applied during the last few years to various inflammatory affections of the interstitial fibrous tissues of the body, which were formerly included under the name of muscular rheumatism. Maxwell Telling, in an article on "Nodular Fibromyositis and its Identity with so-called Chronic Muscular Rheumatism,"[1] called attention to the frequent presence of tender hard nodules and thickening of fibrous tissues in the muscles of patients suffering from this complaint. Llewellyn Jones Llewellyn and A. Bassett Jones are the authors of a comprehensive and able book on Fibrositis. One of the commonest forms of this condition we meet with is that known as—

Lumbago.—The inflammation involves the fasciæ and fascial sheaths surrounding the lumbar muscles, and seems to attack men more frequently than women. In this painful affection the application of local diathermy frequently acts like a charm ; one treatment in some cases has an immediate effect in relieving the pain and stiffness. In my experience lumbago is one of the most satisfactory conditions we are called upon to treat with diathermy. As regards technique, the patient should be treated in a comfortably warm room, so that no chill is felt on exposing the skin of the abdominal and lumbar regions. A well-padded electrode of a thickness corresponding to twelve or sixteen layers of lint is soaked in strong saline solution (one or two tablespoonfuls of salt to a pint of water). The area of the pad is usually about 6 in. square. This is the active electrode. The patient lies down on a comfortable couch, and the electrode is placed under the painful area of the lumbar region, care being taken that even, firm contact is maintained between the skin and the electrode. In patients with arched backs it may be necessary to place a sandbag or small cushion under the electrode in order to keep it in apposition with the skin. A larger indifferent electrode, also well padded, and soaked in saline solution, is now placed on the abdomen, and is kept in position by placing sandbags on the top of it, or both electrodes may be firmly secured in position by means of a many-tailed bandage fastened round the abdomen. Care must be taken that the electrode does not cover the pubic hair, or the patient will complain of a pricking sensation. Having connected high-tension cables to the terminals of the diathermy machine, and also made quite sure that all electrical connections are secure, we may now throw a rug over the patient. The current regulator is placed in the zero position and the main switch turned to the " On " position. The current is then gradually increased. In all medical-diathermy applications it will be found that more current can be passed through a patient by increasing its strength slowly than by doing so rapidly. If you rapidly increase the current, the skin becomes quickly overheated, and you have to switch off before the temperature of the deeper structures is raised. If care is taken, 2½–3 amp. may be passed through the patient for 15–20 minutes before overheating is complained of.

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[1] *Lancet*, Jan. 21, 1911.

In some cases of lumbago I have found it advantageous to follow up this diathermy treatment with chlorine ionization. The electrodes remain in position, and the cables are disconnected from the diathermic terminals and attached to the terminals on the ionization board. The lumbar pad having been made the negative electrode, the current is started from zero and then slowly and gradually increased until the maximum strength desired is reached. Sudden or quick movements of the rheostat must be avoided, both when increasing the current and when diminishing it at the termination of the treatment, in order to save the patient from pain or shocks. When the current is first turned on, a pricking sensation is felt; after a short time this passes off, and the current may be increased a little until the patient feels a mild "mustard plaster" effect all over the dorsal and abdominal pads. This sensation again diminishes, and the current strength can be further increased. When the limit of safety is reached, the burning sensation remains constant and does not diminish. Should the patient at any time complain of burning at one spot, this means that the current density is too great in one place. The current must then be slowly decreased to zero, and the skin examined. The cause may be a fold or wrinkle in the pad of the electrode, or the pad may have become dry and require remoistening with saline solution; occasionally the trouble is due to a pimple or a slight abrasion of the skin, in which case the spot must be protected by some collodion or other protective material before the treatment is resumed. The ionization is continued for 20 minutes. The combined diathermy and ionization treatment is usually given every other day. If desired, salicylic or iodine ions may be used instead of the chlorine ion.

The electrical treatment may in some cases be combined with judicious massage. There is no doubt that experts in the art of massage can promote the absorption of fibrous nodules by causing a flux of blood to the part and breaking down adhesions; at the same time, I believe that considerable harm instead of good may be caused by injudicious massage in cases of fibrositis (*see* p. 61). Violent massage creates trauma, with consequent hæmorrhages between the fascial sheaths and muscle fibres, and it is quite conceivable that these hæmorrhages may become organized into fibrous tissue and form new painful fibrous nodules. There is no doubt that some cases of fibrositis are made worse by massage. Those who have suffered under massage treatment are very grateful for the soothing effect of diathermy applications.

In some cases great benefit is derived from using the static machine and Morton wave current; others are relieved by applying strong faradism with a roller electrode, or combined faradism and galvanism.

Fibrositis of the trapezius (p. 40).—This affection is often met with, and is more common in women than in men, possibly owing, in part, to the constant changing of the coverings of the neck and shoulders in women, e.g. from thick furs to low blouses or evening dress. I have found treatment by diathermy, or combined diathermy and ionization, carried out on the lines suggested for lumbago, equally serviceable in attacks of fibrositis in this situation. In the absence of a diathermy machine, or where only a superficial application of heat is required, the Bertholet bath is a useful method of treatment. Exposure to ultra-violet light may sometimes give relief to the sharp muscular pains of fibrositis. Neither method, however, is so efficacious as diathermy.

Scars and Adhesions

The great value of the scientific application of different electro-therapeutic measures in the treatment of scars and adhesions is hardly realized by the profession at large. The subject is of considerable importance at the present time, owing to the number of war injuries that have to be treated. In all these conditions diathermy holds an important place, either alone or as a preliminary to other forms of treatment; this is especially the case when there is concomitant pain. The passage of the diathermic current causes hyperæmic changes in the tissues which are of great value in promoting absorption of inflammatory products and in improving the local nutrition of the part, in addition to its pronounced analgesic properties. When it is desired to promote the absorption of adhesions by Röntgen radiation, the hyperæmic condition induced by a preliminary application of diathermy is advantageous, as secondary radiations are given off from the iron content in the red blood-corpuscles. The analgesic properties of both diathermy and X-rays are useful in the treatment of painful scars. A. E. Barclay has published an important article on " Electric Stimulation in War Injuries, with special reference to Ununited Fractures,"[1] in which he relates his experience in the early employment of electricity and skilled massage in the treatment of fracture. He considers the sinusoidal current best for exercising the muscles, and says: " The periodicity must be slow, say 500 a minute, in order that we may get good fibrillary tremor of the muscle fibres without causing any tonic contraction." The current is applied without any disturbance of the limb, by the expedient of incorporating a gauze electrode in the splint at the time of its application. The writer lays stress on the evil consequences of prolonged immobilization—atrophy of muscles and bones and the formation of adhesions—and maintains that treatment carried out on the lines suggested in his article, while securing the principle of rest, avoids the atrophic changes which are brought about by " rest " without " activity." He summarizes the results of his investigations as follows:—

"1. The healing of injuries requires the alternation of rest and activity.

"2. Rest, by itself, leads to deterioration of function.

"3. It is possible to maintain function by activity. This can be done either by massage or electrical stimulation.

"4. Electrical stimulation can be applied without violating the principle of rest.

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[1] *Arch. of Radiol. and Electrotherapy*, 1918, xxiii.

"5. Electric stimulation can be applied at any time; the earlier it is applied the less is likely to be the disability due to disuse, and, consequently, the more rapid the healing of the injury.

"6. Some old ununited fractures have united quite satisfactorily, especially those in which there has been some recent operation, even though it be only the removal of a plate; i.e. "freshening," followed by electric stimulation, is likely to be successful.

"7. Some of the sinus cases have ceased to discharge almost at once.

"8. Both skin and muscle are restored to health, even while the limb is immobilized for months."

With a view to stimulating nutrition in the neighbourhood of fractures, dislocations, sprains, etc., use may be made of diathermy, the high-frequency effluve or condenser discharge from the glass vacuum electrode. There are grounds for believing that positive and negative discharges may have distinct physiological effects, and in this connection Mr. G. G. Blake, Assoc. I.E.E., thinks that when high-frequency currents are applied, note should be taken of the direction of the primary current.[1]

Nagelschmidt, in his book, refers to the value of diathermy in the treatment of scars and adhesions as follows: "The favourable effect of diathermy upon adhesions calls for special notice. Just as marked relief from pain is produced after a few treatments in cases of pleural adhesions, scars on skin, traumatic and post-inflammatory inflammation of joints, so in cases with intraperitoneal bands a similar effect is observed. In fact, sometimes after one treatment a complete cessation of all discomfort occurs."

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[1] "Method of obtaining Static Electricity from an Induction Coil, and New Methods for the Application of Static and High-Frequency Currents," *Arch. of Radiol. and Electrotherapy*, Feb., 1919.

Peritoneal adhesions.—In the course of a discussion on "The Electrical Treatment of Wounds, Sinuses Frost-bite and Sprains, considered more particularly in relation to the present War," at the Electro-Therapeutic Section of the Royal Society of Medicine, Turrell made the following remarks on the treatment of the pain and disability resulting from peritoneal adhesions: "It is not to be expected that electrical methods will have any appreciable influence on firmly organized adhesions. These, however, are not cases which give rise to much pain; it is in those cases in which the peritoneal surfaces are glued less firmly together by the exuded lymph, and where movements and friction take place between the roughened surfaces, that most pain is experienced. In private practice I have had two cases where very marked relief has followed the application of diathermy in this condition. In one, a laparotomy had revealed the presence of numerous adhesions from an old appendicitis; there was great pain on movement. The patient was sufficiently relieved after a course of diathermy to enable him to return to his work. I have since lost sight of this case. The other was the case of a lady who for eight years had suffered such pain on any movement that she had become almost a chronic invalid. She was unable to cycle, walk or stoop without producing acute pain. After a rather prolonged course of diathermy she was completely relieved, and has been able to walk, to cycle, and do gardening without any pain for the six months which have elapsed since treatment was discontinued."

C. E. Iredell[1] gives an account of cases of constipation, abdominal pain due to adhesions following operation, chronic colitis, lienteric diarrhœa, and persistent vomiting treated by diathermy. He considers the treatment has a definite action on the intestinal movements, and his results are striking. The method adopted is as follows:

[1] *Proc. Roy. Soc. Med.*, Electro-Therap. Sect., 1919, xii. 34.

Two electrodes 6 in. square are used ; one is placed behind the spleen and one on the abdomen in front of the spleen, and a current of 2 amp. is passed for 20–30 minutes. The position of the pads is then changed so as to include the liver between them, and the diathermy is continued for another 20–30 minutes. The treatment is given thrice a week, or more often, and is continued for a varying length of time.

H. W. Barber[1] reports a case of acne complicated with intestinal stasis which was treated by Dr. Iredell with abdominal diathermy with beneficial results.

Combined diathermy and chlorine ionization is a valuable method of promoting the softening and absorption of fibrous and cicatricial tissues. Ankylosed joints can be successfully treated in this way. Leduc has found that the electrolytic treatment of **pleural adhesions** and of painful dry pleurisies gives results superior to any other method, and says that scoliosis from pleural adhesions following a severe pleurisy or empyema can be prevented if the treatment is begun early enough, or may be relieved if already present. Leduc's method of applying the current is a follows : A footbath of warm saline solution forms the anode. The affected side is covered with sixteen folds of absorbent lint soaked in hot saline solution, and connected to the negative pole. The current is gradually increased until about 100 ma. are running, and the sittings last about an hour. Two séances are given weekly for the first month, then once a week during the second or third months, and afterwards once in two weeks. A 2 per cent. solution of sodium salicylate is used instead of the chlorine ion in some cases of painful pleurisy or intercostal neuralgia.

In cases of septic arthritis followed by **ankylosis** Leduc has used the iodine ion as a sclerolytic agent with success. He points out that the iodine ion has a much more caustic action than the chlorine ion, and therefore the current density must be less, and the sittings should be shorter and given at longer intervals. The following passage is a translation from one of Leduc's papers[1] :—

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[1] *Proc. Roy. Soc. Med.*, Sect. of Dermat., 1919, xii. 37.

"Chlorine ions seem to have a marked effect in producing resolution of scar formations and stiffened tissues. By means of them stiff joints can often be rapidly cured without the need for painful wrenching movements, and under the electrolytic treatment one can see the stiffness disappear gradually from day to day, and the affected joints recover their original power of movement. This result has been noted by myself on many occasions. It is of primary importance that the disease which originally produced the stiffness shall have disappeared, and that no active inflammatory process be going on at the time of the treatment. The best procedure for obtaining this softening of scar tissue is to use a 1 per cent. solution of common salt as the electrolyte, and to apply the cathode to the affected region under this pole. The tissues receive chlorine ions and part with the ions of sodium, and these exchanges seem to modify the chemical constitution of the tissues in the way best adapted for the softening of adhesions and cicatricial tissue. I can quote a case where a stiff wrist of six months' standing, the result of phlegmonous inflammation, had resisted many kinds of treatment, including forcible movements under an anæsthetic, but recovered free movement after two applications of the electric current. Cases of stiff knee have also in many cases become quite free after a few applications of this method. The more accessible a joint is the more easily the results are obtained, and for this reason greater difficulty is found in the treatment of ankylosis of the hip or the shoulder-joint than of such joints as the knee, the wrist or the ankle, which are less covered by layers of the soft tissues."

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[1] Quoted in Lewis Jones's "Medical Electricity," 6th Edit.

The treatment of **facial scars** by ionization is dealt with by Lieut. H. S. Carter and Capt. A. D. E. Shefford.[1] They find that ionization with sodium chloride (chlorine ion) gives the best results, and that the iodides and sodium salicylate are useful for the alleviation of pain. In their opinion the hyperæmia induced in the tissues by the treatment plays a large part in the good results obtained. In cold weather they warm the treated area with hot water or by radiant heat. The use of the diathermy current would be a more effective method of thoroughly warming the area, and would also aid in promoting absorption of the scar tissues.

The static machine has proved of great service in the treatment of the wounded. By using the Morton wave current, static induced current, or static spark, muscular adhesions may be broken down, and stiffened joints moved. Turrell and Humphris, both of whom have had a very large experience with the static machine in the treatment of the wounded, consider it a most valuable apparatus. In the course of his remarks on "The Electrical Treatment of the Wounded," Turrell[2] said :—

"With the Morton wave current of the static machine the muscles to which the electrode is attached require a potential of several hundred thousand volts before a discharge can take place across the 7 or 8 in. spark gap which is often used. So vigorous and of such amplitude is the resulting muscular contraction that we are enabled by this method to free muscular fibres from involvement in scar tissue by the force of their own contraction. So readily and accurately can the force of this contraction be regulated that, by alternately widening and approximating the discharging balls, we can make use of this current as a form of electrical arthro-moteur for the movement of stiff joints in the hands and feet, and as a means of breaking down slight adhesions. This method is specially useful for breaking down the adhesions which persist in trench foot after the subsidence of the acute and painful symptoms. In the Morton wave current these vigorous contractions alternate with periods of complete relaxation, and thus, by a form of auto-muscular massage, the stasis and congestion of recent sprains are removed, and the return of mobility and function is often hastened by several days or weeks. In the same manner, with suitable technique, the reabsorption of the fluid in synovitis of the knee-joint can be rapidly promoted."

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[1] *Brit. Med. Journn.*, Feb. 22, 1919.

[2] *Proc. Roy. Soc. Med.*, Electro-Therap. Sec., 1917, x. 37.

Cases of scar formation associated with ulceration may derive benefit from exposure to ultra-violet light, especially if sepsis is present. In addition to the antiseptic action of ultra-violet light, benefit is derived from the stimulating effect of the hyperæmia induced in the superficial cutaneous structures following a full exposure to the rays. Before treating stiff joints by massage and passive movements, a previous application of diathermy is of great assistance. The active hyperæmia set up in the tissues causes relaxation of the structures surrounding the joints, prevents spasmodic contraction of the muscles, and has, in addition, a powerful analgesic effect. The patient must be encouraged to use his own muscles, and it will be found that diathermy enables him to obtain a bigger range of movement when it is given just previously to the voluntary exercise. This in itself is a great encouragement to the patient, whose muscles are probably wasted from disuse. It is not within the scope of this book to deal with the electrical exercise of muscles following injury to their nervous supply, or with the ionization treatment of septic wounds. Information on these subjects will be found in works on general medical electricity.

DISEASES OF JOINTS

Diathermy is useful in certain types of arthritis as an aid to other methods of treatment.

Gouty arthritis.—Nagelschmidt has found diathermic applications very successful in relieving the pain and in reducing the swelling of inflamed gouty tophi, and states that it is unusual to get a recurrence in the same spot. His method of applying the current is first to use a jet of warm water as an electrode, and afterwards to apply the current by means of a metal electrode. I have had no personal experience in the treatment of acute gout, but have found diathermy useful in relieving pain in joints said to be attacked by " gouty inflammation." Before treating any case of arthritis it is a good plan to make an X-ray examination of the affected joint or joints ; the information gained may be of great value as regards both diagnosis and prognosis, and will also serve as a guide to the physician or surgeon in deciding upon the treatment most likely to benefit the case. I have found application of the glass vacuum electrode very useful in some cases of inflammation attacking the first metatarso-phalangeal joint. This treatment may be either given alone or combined with ordinary diathermy. Good results have been obtained in the treatment of gout by high-frequency applications on the condenser couch. Numerous sittings are necessary. The gradual amelioration is apparently due to improvement in the peripheral circulation.[1]

The diathermic applications may be followed by ionization. Salicylic ions can be introduced at the negative pole, and lithium ions under the positive electrode, simultaneously. Good results may be obtained by ionization alone in cases of chronic gout.

Libotte of Brussels[2] reports successful results from high-frequency applications in cases of acute and chronic gout. The electrodes are placed on the affected areas, and treatment is given every other day.

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[1] Bonnefoy, " L'Arthritisme et son traitement par les courants de haute fréquence et de haute tension." 1907.

[2] *Arch. d'Élec. Méd.* 1914, xxiv. 596.

Osteo-arthritis.—This includes conditions which were commonly grouped under the unsatisfactory and indefinite name of "rheumatism." Our nomenclature of joint affections leaves much to be desired. We know from experience that many cases of so-called rheumatoid arthritis are due to the presence of some septic focus in the body, and, except for securing temporary relief from pain and swelling, it is useless to treat the local condition until the exciting cause is removed. The help of X-ray evidence is called for in these cases, with a view to obtaining more accurate information as to the condition of the affected joint or joints. When extensive bony changes are found, electrical treatment can do little, except, perhaps, cause temporary amelioration of symptoms. On the other hand, an X-ray examination may yield no evidence of bony changes, and the case may turn out to be one of fibrositis or perineuritis ; in which case both general and special treatment are called for and we are justified in giving a patient an encouraging prognosis. It is to be noted that "early" cartilaginous changes in a joint may give no evidence of their presence in an X-ray plate. I have on several occasions seen cases labelled rheumatoid arthritis which on X-ray examination proved to be cases of tuberculous arthritis. The danger of prescribing massage and passive movements in this condition is obvious.

Electrical treatment is valuable in many painful joint conditions in which the inflammatory mischief is confined to the soft parts. Diathermy, either alone, or combined with chlorine or salicylic ionization, is valuable in relieving pain and in promoting absorption of inflammatory products. The active hyperæmia induced by diathermic applications is of great value, and enables us to obtain results which were impossible before. In many cases of chronic inflammatory joint affections it is impossible to discover the exciting cause of the trouble, and occasionally these cases recover spontaneously. In no case can arrest of the disease be expected until the exciting cause ceases to operate. Laquer[1] has demonstrated that thermo-penetration diminishes the activity of infective micro-organisms in articulations, and favourably influences rheumatic and gonorrhœal articular affections. Berndt, Nagelschmidt, and Kling Müller and Simon published successively new cases of gonorrhœal, rheumatic and gouty arthritis treated with success by diathermy.[2]

Gonorrhœal arthritis.—The good results obtained by diathermy in the treatment of this disease appear to be due to the vulnerability of the gonococcus to heat. This organism is killed at a temperature of 39° C. (102·2° F.). The rise of temperature in a joint treated by diathermy diminishes or destroys (Nagelschmidt) the vitality of the gonococcus; on the other hand, the active hyperæmia induced increases the nutrition and resisting power of the tissues. In discussing the physiological effects of diathermy currents, Zimmern points out that when the temperature rises to 50° C. (122° F.) the heat becomes painful and can no longer be tolerated. We are therefore unable to destroy other types of micro-organism *in situ* by diathermic currents applied for medical purposes.

Berndt[3] discusses the question of destroying the gonococcus within the joint by means of diathermy, without destroying the vitality of the joint structure; he advises diathermic application in all acute and recent cases. Laquer reports good results in subacute gonorrhœal arthritis by such applications.[4] The continuous current also is useful in gonorrhœal arthritis, good results having been reported from both salicylic and chlorine ionization in acute, subacute and chronic cases. Adhesions following gonorrhœal infection of a joint are best treated by diathermy followed by chlorine or iodine ionization.

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[1] *Zeits. für physik. u. diat. Therapie*, 1918, xxii. 243–49.

[2] Rapport sur la Diathermie, by Bergonié et Réchou, *Arch. d'Élec. Méd.*, 1911, xix. 71.

[3] *Zeits. für physik. u. diat. Therapie*, 1909, p. 167.

[4] *Ibid.*, p. 277.

Lewis Jones[1] reports two cases of stiff joints left after gonorrhœal arthritis which were successfully treated by chlorine ions.

Joint injuries.—Recovery from *sprains* can be materially assisted by electrical treatment. Diathermic applications are a very valuable means of relieving pain, congestion and stasis in case of sprains, and if synovitis is present, absorption of the fluid is promoted. The Morton wave current is also most useful; if necessary, it may be combined with diathermy. Sprains, too, can be quickly relieved by continuous-current applications, either chlorine or salicylic ions being used. The negative electrode should, if possible, be wrapped completely round the joint, and the positive indifferent electrode applied to some other part of the limb. In acute cases electrical treatment should be given daily, and in chronic cases on alternate days. When there has been severe tearing of ligaments diathermy or ionization is, in my opinion, the method of choice; in these cases early massage and passive movements are contra-indicated.

Bergonié and Réchou report a case of severe traumatic arthritis of the right knee which had been treated for many months by massage and hot air without benefit. Electrodes were placed on the anterior and posterior aspects of the knee-joint, each electrode having an area of 200 sq. cm. A current of 3 amp. was passed, and the séances were of 10 minutes' duration. From the first, pain disappeared, and after 10 séances the patient left the hospital cured.

Chronic synovitis may in some cases be considerably improved by iodine ions. It is advisable to examine by X-rays all patients suffering from sprains. It may not be absolutely necessary, but in the interests of the patient's medical attendant alone, apart from those of the patient, it is most certainly called for. Radiologists are frequently asked to radiograph the joint of a patient who has left one medical attendant and sought further advice because a supposed sprain has not got well. The second medical attendant sends the patient for X-ray examination. In many cases of supposed sprain, a fracture is discovered; often it is a mere crack in the bone, quite impossible of diagnosis by clinical methods.

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[1] *Op. cit.*, p. 478.

CHAPTER IX

THORACIC AND OTHER AFFECTIONS

Pulmonary tuberculosis.—Diathermy has been used by various workers in the treatment of this disease. I have no personal experience to cite, and to my mind the published results are anything but convincing. Moreover, diathermic applications in this disease are not without grave danger to the patient.

Nagelschmidt[1] says that in early tuberculous infection without complications a fair amount of current may be passed through the lungs, but that in the second and third stages great care is necessary. If there is the slightest tendency to hæmorrhage an amount of secondary arterial hyperæmia sufficient to rupture one or more blood-vessels may be produced. Diathermic applications are said to cause first an increased secretion of mucus of lighter consistency; then, after a few days, the secretion becomes less and patients show improvement, both subjectively and objectively. The nightsweats stop and the temperature drops, the existing mixed infection improves and weight is increased. The appetite and digestion also improve. If the treatment is given two or three times weekly, even severe cases are reported to improve with apparent arrest of the disease. Other cases relapse sometimes after a few weeks. The electrodes used are 10 × 20 cm. (4 × 8 in.), and the current strength employed is 1–1½ amp. De Kraft prefers to use bare metal electrodes in this disease. He refers to the fact that mitral disease causes congestion of the lung and is rarely associated with tuberculosis of this organ. Diathermy usually strengthens the condition of the heart, but its effect must be carefully watched, especially when the blood-pressure is low, for fear of sudden collapse. Nagelschmidt does not think it necessary to employ large currents. Diathermy has probably no direct action on the tubercle bacillus or its toxins; the therapeutic effects appear to be due to the stimulation of the heart and the arterial hyperæmia.

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[1] Quoted by de Kraft in *Journ. of Advanced Therapeutics*, 1916.

W. B. Snow of New York reports good results in the treatment of pulmonary tuberculosis by the combined use of high-frequency currents and X-rays. Patients gain in weight at the rate of 2 lb. a week under the treatment.

Thielle has published his experience of high-frequency currents in this connection. The stimulating effect of strong high-frequency discharges to the chest is recommended by some workers. Williams, Oudin and Denoyes have published the results of their experiences in this method of treatment. The good effects following the X-ray treatment of tuberculous glands, lupus, etc., would suggest a promising field for their employment in pulmonary tuberculosis, and some workers have already reported encouraging results.

Pneumonia.—The crisis of pneumonia is reported as being hastened by diathermy applied to the chest.

Pleuritic effusion.—I have had experience in one or two cases of tuberculosis of the lung associated with pleural effusion in which diathermic applications have appeared to hasten absorption of the fluid. This is a result that our knowledge of the action of diathermy would lead one to expect. The electrical treatment of pleural adhesions is dealt with at p. 79.

Diseases of the eye.—Diathermy may be usefully employed in cases where the oculist desires to apply warmth and set up an active hyperæmia in the eyeball and its environment. A small well-moistened pad is placed over the closed eyelid, a larger indifferent electrode being placed in some convenient situation, or the patient may hold a metal diathermy handle, and the current strength is regulated so that he feels a comfortable warmth. Iredell and Ryley report some interesting cases of chronic inflammatory conditions of the eye treated by means of a diathermy cup electrode filled with a normal saline solution and applied to the eyeball. The treatment was given either twice a week or every other day, and lasted 5–30 minutes, the strength of current used being about 0·3 amp. No harmful effects resulted from the treatment, and a general improvement occurred in every case.[1]

Chronic urethritis.—Some workers have applied diathermy to the urethra by means of metal sounds with the object of killing the gonococcus *in situ*. As already stated (p. 85), this organism is known to be easily destroyed by heat. A. C. Geyser[2] first renders the urine alkaline by administering sodium bicarbonate. He then stops all sodium chloride intake by administering a salt-free diet. The technique employed is as follows: An ordinary steel sound is inserted into the urethra, and the temperature is raised to 108° F. This heat is maintained for at least an hour daily for three days, and the gonoccocus is said to be killed by this procedure. Geyser also injects 15 drops of colloidal iodine into the urethra. All treatment is stopped after three days. The above manipulations are difficult, great care being needed to prevent local damage to the delicate tissues of the urethra.

Ernest Roucayrol[3] has also employed diathermy in this disease. I have had no personal experience in this connection. A perusal of the literature suggests that at present it is not a safe method of treatment.

Gonorrhœal orchitis.—De Kraft applies diathermy in this disease by means of a special cup electrode with a metallic connection. The bottom of the cup is filled with plain water and connected to one pole of the machine. A metal plate is placed on a stool, and the patient sits down with the scrotum in the cup electrode. The current is then gradually turned on until distinct heat is felt in the scrotum and both sides of the groin. De Kraft has obtained rapid and complete results from this method of treatment.

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[1] *Proc. Roy. Soc. Med.*, Electro-Therap. Sect., 1919, xii. 31.

[2] *New York Med. Journ.*, June 30, 1917.

[3] *Bull. de l'Acad. de Méd.*, 1917, lxxvii. 637-80.

Incontinence of urine.—The diathermy rectal electrode has been found useful in the treatment of incontinence occurring in old men as the result of atony of the sphincter muscles, or chronic vesical irritation as in diabetes mellitus.[1]

Congestion of the liver.—Diathermy is used in this condition with a view to relieving the stasis and venous engorgement.

Nephritis.—Various workers have used diathermy in the treatment of this disease. I have had no personal experience. The treatment is applied locally over the renal area in chronic nephritis.

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[1] De Kraft, *Amer. Journ. Elec. and Rad.*, Nov., 1917.

PART III.—SURGICAL DIATHERMY

CHAPTER X

PRINCIPLES AND TECHNIQUE

THE difference between applying diathermy for medical and for surgical purposes lies in the fact, already touched upon, that in the former the endeavour is to raise the temperature of the tissues within physiological limits ; in the latter this limit is exceeded, and tissue is destroyed. If the current is concentrated on a small area by means of special electrodes (Figs. 21–25), its strength, i.e. its density, can be increased so that destruction of tissue takes place. Various experiments may be conveniently made on a piece of beefsteak to demonstrate the surgical action of diathermy with electrodes of different sizes and shapes, applied for different periods of time, and with current of different strengths. It must, however, be remembered that there is a difference between operating upon dead and upon living tissues : the latter are bathed in the circulating fluids of the body, which rapidly carry away the heat, and, in addition, the presence of large vessels and other important structures has to be kept constantly in mind.

Advantages and drawbacks.—The chief advantages and disadvantages of surgical diathermy may be thus epitomized :—

Advantages

1. Tumours otherwise inoperable may be attacked.
2. The operation is more or less bloodless.

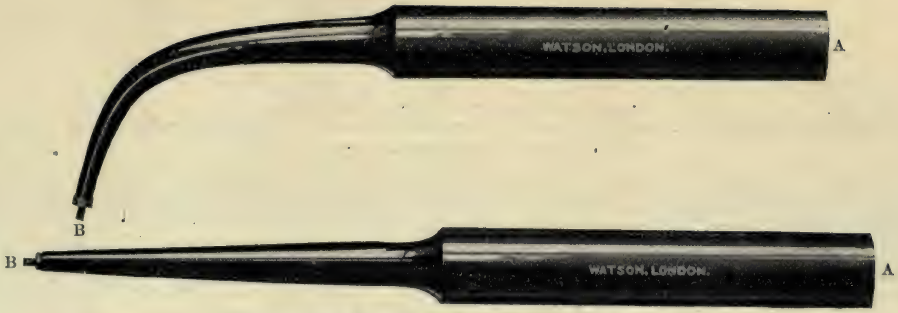

Fig. 21.—Surgical electrodes.

A, A, Screw attachments for diathermy cables ; B, B, Threads for screwing on active electrodes.

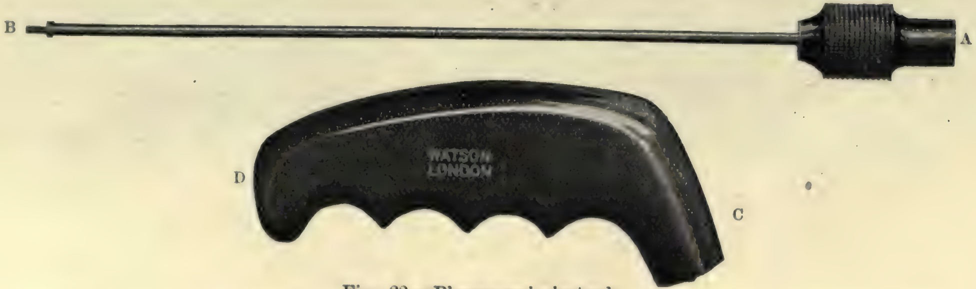

Fig. 22.—Pharyngeal electrode.

A, Plug into C ; B, Thread for screwing on active electrodes ; C, Distal end of ebonite handle ; D, Screw in ebonite handle for attachment of cable from diathermy machine.

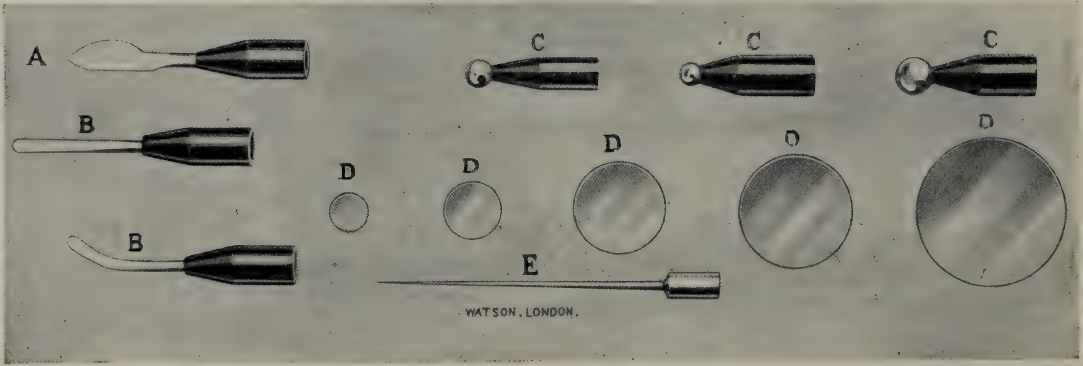

Fig. 23.—Surgical electrodes.

A, Knife electrode designed by Cumberbatch ; B, Blunt-knife electrodes ; C, Button electrodes ; D, Disc or plate electrodes, varying in diameter from ⅛ in. to 1 in. ; E, Needle electrode.

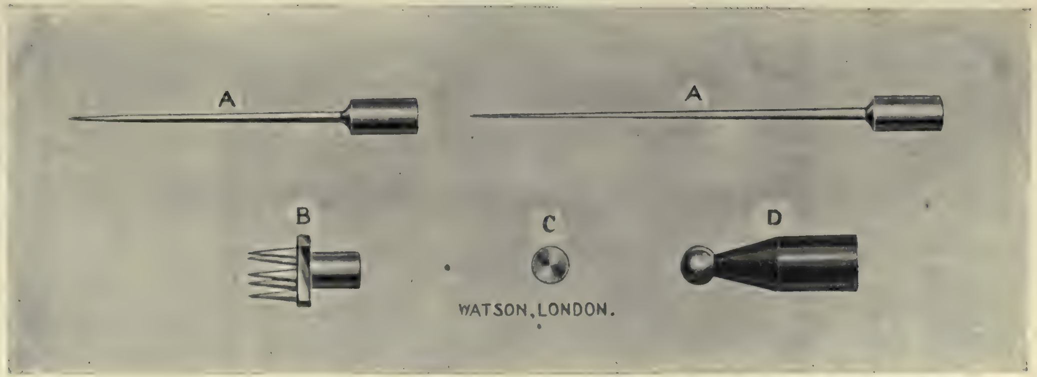

Fig. 24.—Surgical electrodes.

A, Needle electrodes ; B, Plate electrode fitted with short needles ; C, Disc or plate electrode ; D, Button electrode.

3. The dangers of metastasis are much less than with a cutting operation owing to the sealing of the blood-vessels and lymphatics draining the part.
4. Sterilization of the parts.
5. There is complete destruction of visible and palpable malignant disease.
6. The operation is rapid and easy.
7. There is no surgical shock.

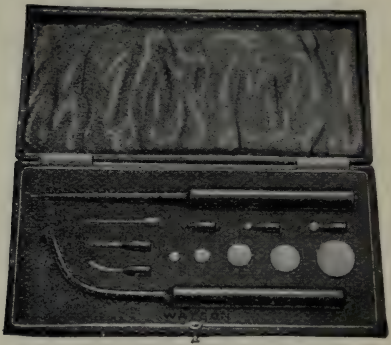

Fig. 25.—Surgical electrodes in case.

8. Convalescence is rapid.
9. The formation of adhesions is rare.
10. The operation can easily be repeated if necessary.

Disadvantages

1. Healthy and diseased structures are equally destroyed.
2. The surgeon cannot see important vessels and nerves.
3. There is danger of secondary hæmorrhage when operating near large blood-vessels.
4. There is a tendency to formation of cheloid in operations involving skin surfaces.

Experimental.—The following are a few simple experiments with a thick piece of raw beefsteak :—

1. Lay the steak upon a large indifferent electrode connected to one terminal of the diathermy apparatus.

Take one of the disc electrodes and connect it by means of the special universal handle to the other terminal of the machine.

Hold the disc electrode firmly against the upper surface of the piece of steak on the large indifferent electrode, and turn on the current. After two or more seconds, the time depending on the diameter of the disc electrode chosen and the strength of current used, bubbles of steam appear and sparking occurs round the edges of the disc. The current must now be switched off. The piece of steak under the active electrode it will now be found to be hot and coagulated, and cooked to a depth approximately equal to the diameter of the disc used. The sparking round the edges of the disc is due to the fact that the dry coagulated tissues under the electrode do not conduct the current, and the sparking is the attempt of the current to jump to moist tissues which are not coagulated. The difference between applying a red-hot electric cautery and a cold diathermy electrode for the destruction of tissue lies in the fact that in the former case the tissues are heated from without inwards by conduction from a " hot " metal, whilst in the case of the latter we apply a " cold " metal and the heat is developed in the tissues themselves owing to the resistance they offer to the passage of an electric current; the " cold " electrode itself, in fact, becomes heated as a " result " of the heat developed in the tissues. The very opposite conditions, therefore, obtain in the application of the heated electric cautery; here the tissues rapidly " cool " the electrode, especially when a vascular part is being treated, and, owing to their poor conductivity, only a superficial charring effect takes place as compared with the deep penetration obtainable with a diathermy electrode.

2. (*a*) Take a needle electrode in place of the disc electrode and draw its point over the surface of the steak.

Sparks will pass between the needle and the steak, and incisions can be made in the surface of the latter. In the case of the living subject, deep incisions can be made without hæmorrhage occurring.

(*b*) Plunge the needle electrode into the steak perpendicularly and switch on the current. The tissues will be coagulated around the needle to a depth of 2–3 mm., the depth of coagulation depending on the strength of the current and the length of time it is allowed to flow.

3. Take a piece of steak 1 in. square and apply two disc electrodes, each 1 in. in diameter, to opposite sides of it. The current being turned on, the steak rapidly becomes coagulated through and through.

4. If, in Experiment No. 3, instead of two electrodes of equal size being used, one electrode is smaller than the other, coagulation will first occur under the smaller electrode.

5. Cut a piece of steak into the shape of an hour-glass or dumb-bell, and apply electrodes to either end of it larger than the narrowest diameter of the steak. Coagulation will take place first in the narrowest part of the isthmus or waist joining the two larger ends of the steak, owing to the current density being greatest at this point.

In this connection the reader may also be referred to the experiment with egg-albumen described in the section on the physiological effects of diathermy (p. 24).

The foregoing simple experiments teach us that heat is generated between a pair of diathermy electrodes, and that wherever the current density is great enough, coagulation of tissue takes place.

The points observed will be found to have a very practical bearing when we come to apply diathermy for surgical purposes to the living subject. I have refrained from mentioning the number of amperes necessary to produce coagulation and destruction of tissue in the various experiments described, as I regard the amount of current actually registered on the meter, even if it were accurate, as of little practical value when performing an operation on the living subject.

In actual practice, the amount of current used may be anything from half an ampere up to two or more amperes; the operator, however, judges the amount of current necessary in any particular operation by the effects it produces, and not by the amount the ammeter may happen to register at the moment.

Diathermy, as we have seen, destroys both healthy and diseased cells; it is possible that the latter may be more easily destroyed than the former, but we have no definite evidence of this. The destructive process extends beyond the area of visible coagulation (Fig. 26).

Technique of surgical diathermy.—A general anæsthetic is usually administered in surgical cases. Some small operations may be performed under a local anæsthetic. Two electrodes are used, one a large flat pliable indifferent electrode, usually not less than 8 in. or 10 in. square. Personally I find limpet material convenient to use. The metal is covered with a thick pad of gamgee tissue well saturated in warm saline solution (two tablespoonfuls of NaCl to a pint of water). The most careful attention must be paid to the application of this electrode, or serious burns will occur. Make sure of the following points before switching on the current:

1. That no bare metal or wire touches the patient.
2. That the fixing of the high-tension cable to the large indifferent electrode is quite secure, and that the insulation of the cable itself is sound.
3. That the pad covering the indifferent electrodes is thoroughly saturated all over, i.e. that no dry areas exist. Be sure there are no folds or creases in the wet pad.
4. The indifferent electrode must make even and firm contact with the skin of the patient at all points. Steam may accumulate and cause burns

if there are any gaps between the skin and the pad.

5. The skin must not be in metallic contact with the operating table at any point.
6. If the patient is moved on the couch after the indifferent electrode is placed in position, make sure again that everything is safe.
7. If the operation is a prolonged one, it may be necessary to remoisten the pad. A strip of gauze or bandage may be used as a wick connecting the indifferent electrode to a basin of warm saline solution. In any case, make sure that the pad does not become dry.

After the operation it is advisable to examine that part of the skin which has been in contact with the indifferent electrode. The choice of an active electrode depends upon the particular character and situation of the part we are called upon to treat. The active electrode consists of an ebonite handle through which a metal core passes. The cable of the diathermy machine screws into its proximal end, and active electrodes of various types may be screwed into the distal end. Fig. 23 shows some of the usual types of active electrodes. They may take the form of—

1. Circular or oval metal plates varying in diameter from $\frac{1}{8}$ in. up to 1 in.
2. Circular or oval plates fitted with one or more short needles. The needles enable a deeper and more extensive coagulation to be produced, and also serve to anchor the electrode during its application.
3. Needle electrodes. These are used when we wish to destroy only small portions of tissue. When embedded in the tissues, coagulation occurs to a greater depth than when using the disc or button electrodes. They are useful for trans-

fixing papillomata at their base, and also in the treatment of nævi.

4. Button electrodes. These are useful for application to the base or cavity left after removal of a malignant mass.
5. Blunt-knife electrodes.

Cumberbatch[1] describes and shows by reproductions of photographs the results of experiments he made with raw beef to demonstrate the distance coagulation extends when needle and plate electrodes are used.

When everything is ready the surgeon grasps the ebonite handle and places the active electrode in contact with the tissue he wishes to destroy. The current is then switched on and its strength gradually increased from zero until the effect desired in any particular case is produced.

We will assume that the operator wishes to coagulate the base of a malignant ulcer or mass involving the skin or mucous membrane of the mouth. A flat disc electrode of suitable size is chosen and pressed firmly on the part to be destroyed. The current having been turned on, bubbles of gas and steam are given off, and in one or more seconds (the time depending upon the diameter of the disc electrode chosen and the strength of the current used), crackling sparks jump from the edges of the electrode to the surrounding uncoagulated tissue.

The current should be switched off immediately sparks begin to appear, as stimulation of nerves and violent contractions of the neighbouring muscles are caused. For the same reason it is advisable to switch off the current before removing the electrode from the part treated. On examination of the tissue under the electrode it will be found to be hot, dry, and white in appearance ; it has been coagulated, the depth of coagulation depending upon the factors already mentioned. It is not desirable to scrape away the coagulated tissues, because of the liability to hæmorrhage. The surgeon must aim at performing a bloodless operation.

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[1] *Arch. Röntgen Ray*, Dec., 1914.

The suitable strength of current to use in any particular case having once been found, the current regulator may be left in position for the next application of the electrode. What happens when a case is treated in this manner may by roughly represented diagrammatically (Fig. 26). The current density, and therefore the heating effect, are greatest under the small electrode, A, and least under the large indifferent electrode, F. The operator must bear in mind the possibility of coagulating the wall of a large blood-vessel. There is danger of severe hæmorrhage when the sloughs separate if the wall of a large artery is coagulated. Great care must therefore be taken when an operation is performed in close proximity to important vessels. In those cases in which the diseased area surrounds a large artery, a preliminary operation in order to ligature the vessel is performed.

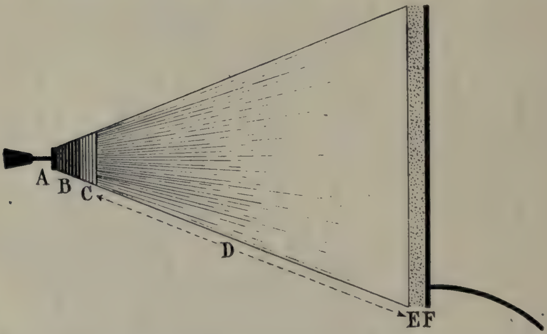

Fig. 26.—Diagrammatic representation of what occurs under active electrode in surgical diathermy.

A, ¼-in. active disc electrode. B, Tissues visibly coagulated to a depth approximately equal to the diameter of the disc electrode used. C, Area of tissues in which the current density has been insufficient to cause coagulation, but has probably been sufficient to destroy the vitality of the cells. D, Gradual diminution of current density and heating effect. E, Thick pad of gamgee tissue saturated in warm saline solution (1 oz. of salt to 1 pint of water). F, Large indifferent metallic electrode.

Care is also necessary when coagulating tissues over bone, as destruction of the periosteum means a tedious convalescence. Fragments of dead bone separate from time to time, and many weeks may elapse before the overlying tissues finally heal over this area. When possible, this dead bone may be removed to facilitate healthy granulation.

Various workers lay stress on the necessity for strict aseptic precautions in diathermic operations, as in all surgical operations.

Strict asepsis does not appear, however, to be necessary when operating on cavities like the mouth and pharynx, micro-organisms having little chance of surviving the application of a diathermic cautery.

If, however, the usual surgical knife or other instruments are used to remove or divide tissues, these must be sterilized. Cumberbatch has designed a special knife electrode (Fig. 23, A) for use in the case of growths which are freely movable over the subjacent structures. He describes the method of using this electrode as follows:—"A metal end piece shaped like a scalpel blade, 1–1½ in. long and ⅛-in. wide, is used. The free end is placed in the healthy tissue a little beyond the advancing edge of the growth, the current is switched on, and as coagulation begins, the end of the electrode is pushed gradually deeper. The blade is slowly advanced round the edge of the growth, its progress always being preceded by coagulation, which occurs in front of it. In this way the malignant mass is gradually freed and raised from its bed, and is finally removed from a bloodless cavity with coagulated walls."[1]

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[1] *Op. cit.*, p. 244.

CHAPTER XI

SURGICAL APPLICATIONS OF DIATHERMY

THIS chapter may begin with a list of some of the conditions to which surgical diathermy is applicable ; it indicates the wide scope of this treatment. There is no doubt that with further experience of this powerful addition to our surgical armamentarium results will improve. The future of surgical diathermy is a distinctly promising one. The list is as follows :

1. Superficial Lesions : Telangiectases. Port-wine marks. Flat warts. Moles. Nævi. Acne. Freckles. Urethral papilloma. Urethral caruncle. Xanthoma.
2. Papillomata of the skin and mucous membranes.
3. Chronic or malignant ulcerations involving the skin or mucous membranes.
4. Malignant growths, especially those of the mouth and naso-pharynx.
5. Various inoperable growths.
6. Papillomata of the bladder.
7. Vascular tumours.
8. Rodent ulcer, etc.

Superficial cutaneous blemishes.—Such lesions as moles, flat warts, port-wine marks, capillary nævi, telangiectases, acne, freckles, xanthoma, caruncle and urethral papillomata may be treated by *diathermic fulguration.* This very simple and efficient process was described by Turrell at a meeting of the Electro-Therapeutic Section of the Royal Society of Medicine in March, 1916.[1] The patient lies on the diathermic or high-frequency condenser couch. One terminal of the machine is connected to the metal plate under the couch, and the other to the handle or handles of the couch, which are grasped by the patient. He thus becomes part of a charged condenser, as in ordinary condenser-couch treatment. It is not necessary for the operator to possess a special condenser couch, it being quite a simple matter to arrange a condenser system, provided that an ordinary wooden consulting-room couch is available. All that is required is a sheet of pliable metal such as limpet material, 18 in. or 2 ft. long by 12 in. broad. One cable of the diathermy machine is securely fastened to a corner of the sheet of metal, and the latter is laid flat on the couch. A thick sheet of rubber such as is used to protect X-ray operators, or a sheet of ebonite, is placed on top of the metal plate, and over this a cushion or thickly folded rug.

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[1] *Proc. Roy. Soc. Med.,* Electro-Therap. Sect., lx. 92.

The patient sits or lies on top of this insulating material, and holds in his hand a metal handle attached to the second terminal of the apparatus. If the current is now turned on ($\frac{1}{4}$–$\frac{1}{2}$ amp. is sufficient) and a pointed metallic instrument held by the operator is brought close to the skin, without touching it, sparks will pass from the skin to the instrument. In the treatment of small cutaneous blemishes a pointed silver probe, or a fine or blunt needle electrode, may be used. In order to ensure steadiness and accuracy, an ebonite rod or other non-conductor held in one hand, with one end of the rod resting on the patient, may be used as a support for the operating hand. Everything being ready, the current is turned on to the desired strength and the point of the metallic instrument is gradually brought to within about $\frac{1}{16}$ in. of the part to be destroyed, care being taken not to touch the skin of the patient with the hand. Sparking then occurs, and in a few seconds (the time depending upon the area and condition under treatment) the necessary destruction has taken place. Pain, if felt, is only slight, little or no inflammatory reaction follows the treatment, and no dressing is required. The desiccated area crumbles away in a few days. In the treatment of small blemishes little or no scarring results.

Papillomata of the skin and mucous membrane.—These may be treated in two ways: (1) By diathermic fulguration, as just described. (2) By means of a needle electrode under local anæsthesia.

The large indifferent electrode, connected to one terminal of the apparatus, is placed in a convenient position, and the active needle electrode is either made to transfix the base of the growth or is pushed through the free end down to its base. Coagulation takes place around the needle for a variable distance, depending upon the character of the growth and the strength of the current used. The growths are left to slough off by themselves.

Nævi.—Large nævi involving mucous membranes may be successfully attacked by diathermy. Needle electrodes are used to transfix the tumour. When treating cavernous nævi under the skin, special precautions must be taken to avoid injury to the skin.

Cumberbatch uses a wire insulated with enamel as an electrode for this purpose. His method of operating is as follows: "A needle for subcutaneous injection is passed through the skin into the nævus, one at each side. A wire, insulated by enamel, is passed along each needle to its tip, and the current is passed between the ends of the insulated wires. By this method the skin is protected from the current at the point of entry of the electrode. The current is increased cautiously and the finger is placed on the skin over the nævus. If the skin is felt to become very hot, the current must be diminished or cut off."[1]

Papillomata of the bladder.—Diathermic treatment is the best means of destroying these growths. There are two methods of operating: (1) The open suprapubic method. (2) The perurethral method.

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[1] *Op. cit.*, p. 248.

(1) *Suprapubic operation.*—Mr. Herbert Frankling, C.B.E. (Harrogate), has kindly supplied the following description of the technique of the operation, as performed by us:—

"After a preliminary cystoscopy and mapping out of the tumours the patient is anæsthetized and placed in the moderately high Trendelenburg position, and the bladder is moderately distended. The bladder, when exposed, is steadied by two laterally placed sutures, the ends of each being clamped together with Spencer Wells forceps. These sutures serve to control the cut bladder edges in the subsequent stages of the operation. A suprapubic opening sufficiently large to give a good view of the bladder cavity and the villous growth or growths is made. Adequate exposure is facilitated by the use of suitable retractors. It is usually recommended that these should be of wood, but we have found no disadvantage in the careful use of metal ones. Intact mucous membrane is carefully packed away by means of *wet* gauze swabs, to avoid the implantation of any tumour cells during subsequent manipulations, which for the same reason must always be carried out in the most gentle manner possible. If a pedicle be present, it is seized with delicate right-angled forceps and put on the stretch (Fig. 27), great care being taken that the villi are not in any way injured; it is then burnt off quite close to the bladder wall with the curved diathermic knife—this burning extends out on to the bladder wall, which has been pulled up by the traction on the pedicle. A charred oval area, greater or smaller according to the degree of the traction exercised, is thus left (Fig. 28). If there be any doubt as to the non-malignancy of the tumour—some authorities regard these papillomata 'from the first as papillary carcinomata'[1] and that is certainly the 'safer assumption from a surgical standpoint and is protective of the best interests of the patient '[1]—and remembering that malignant changes are prone to take place, 'especially about the pedicle,' [2] the area left after removal may with advantage be further treated with the button electrode.

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[1] MacCallum, "Textbook of Pathology," p. 939.

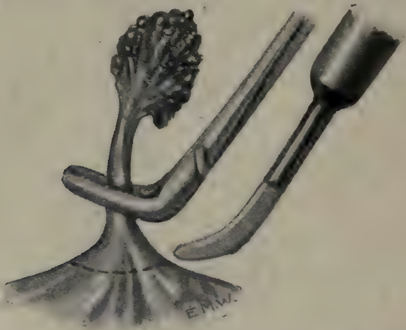

Fig. 27.—Villous papilloma of bladder seized with right-angled forceps.

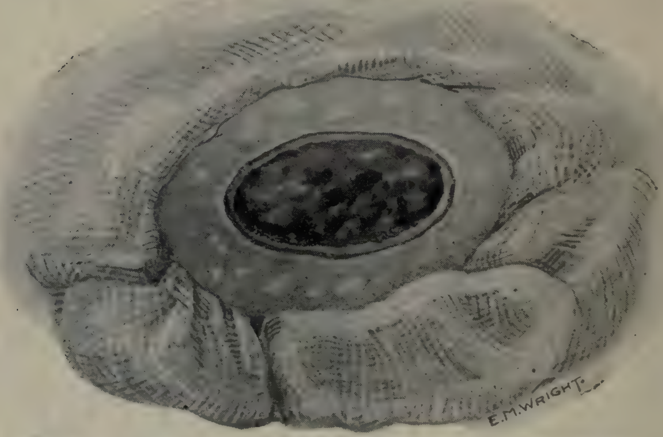

Fig. 28.—Charred area left after removal of papilloma of bladder.

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[1] Kelly & Burnam, "Diseases of the Kidney and Bladder," ii. 512.

[2] O. Zuckerkandl, quoted by Kelly & Burnam, *op. cit.*, p. 513.

"Subsessile and sessile tumours may be treated in a similar fashion, full advantage being taken of the possibility of 'pulling up' the mucous membrane of the bladder wall at and around the tumour base, and due regard being paid to the possible proximity of a ureteral opening (Figs. 29–32).

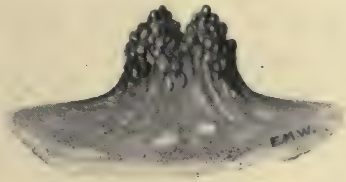

Fig. 29.—Villous papilloma of bladder, sessile variety.

"The proper application of the forceps for holding the tumour whilst it is being burnt off can be facilitated by picking up the mucous membrane just beyond the growth on either side by small toothed forceps with delicate jaws and teeth, and thus pulling away the growth with its basal mucosa. If it should be impossible to apply the holding forceps to the base of the tumour well below its main mass, the mucosa must be incised around the base, leaving an adequate margin of healthy tissue (Fig. 33). Picking this up in forceps at one point, the area

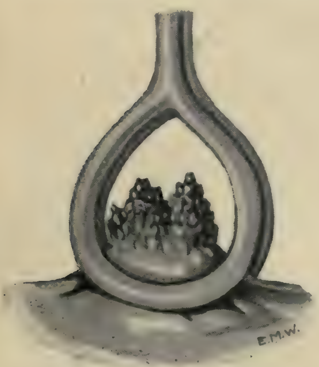

Fig. 30.—Forceps applied.

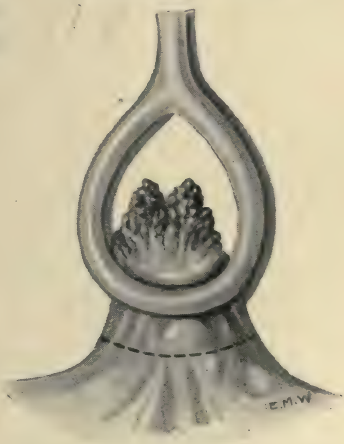

Fig. 31.—Mucous membrane of bladder well pulled up.

marked out is dissected away, any suspicion of malignancy being met by removal of the deeper muscular coat of the bladder as well as the mucous membrane, the diathermic knife being of course used throughout. Too much stress cannot be laid on the necessity for the utmost gentleness in handling the tumour. Any crushing or other injury will result in abnormal epithelial cells being detached and possibly becoming implanted on the mucous membrane.

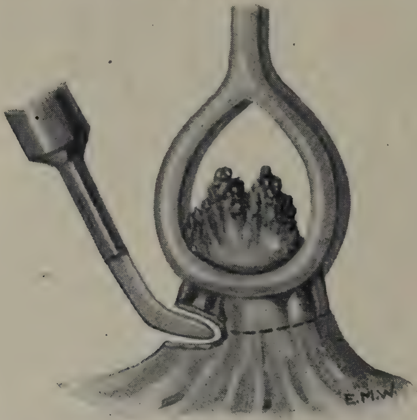

Fig. 32.—Diathermic knife cutting through base of tumour.

"A convenient forceps for holding the tumour base is a ring forceps with ring sufficiently large to encircle the main tumour mass without catching the villi in its bite. We have had made for us by Thackray of Leeds such a forceps with the ring part boxed in with thin metal, so that when it is clamped across the base of the tumour the villous mass is enclosed in a small chamber. We think that in practice the utility of this is small. Small 'splashes' of villous growth may be destroyed *in situ* by the small ball electrode.

"As a rule there will be no bleeding from the base of tumours removed in this way, but should there be any oozing, it is readily checked by a touch of the electrode.

"When it is certain that no growth has been overlooked, the swabs are removed and the bladder cavity is flooded with alcohol to kill any loose abnormal cells that may be present, and the bladder, if aseptic, is stitched up with interrupted catgut sutures, either wholly or leaving a space large enough to admit a small safety drain-tube. The parietal wound is sutured in the usual way.

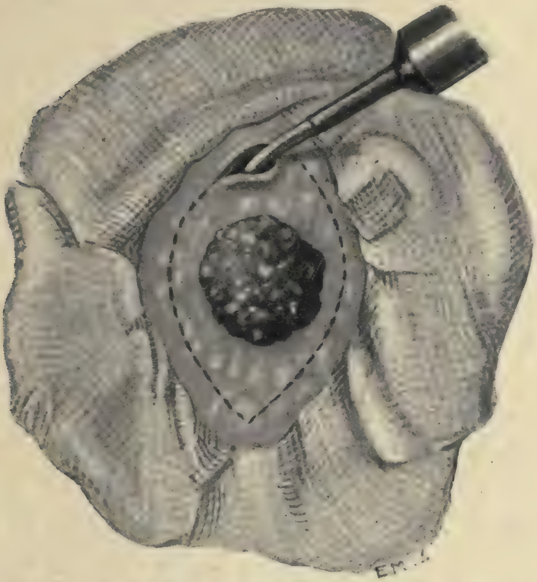

Fig. 33.—Removal by diathermic knife of tumour of which the base cannot be held by forceps.

"The separation of the slough is as a rule unnoticed. Occasionally we have noted about the tenth day a slight hæmorrhage, together with the passage of a slough large enough to be obvious. In aseptic cases the bladder is not washed; the tube is removed on the third or fourth day, and there is seldom much leakage afterwards."

(2) *Perurethral operation.*—I have had no personal experience of either the unipolar or the bipolar method.

Edwin Beer of New York was the originator of a practical method of destroying intravesical tumours by high-frequency currents *per urethram.* He published his first paper in 1910 (*see* Bibliography), and has had a large experience of this treatment. Experimenting with raw beef cut in the shape of an hour-glass, he found there was a slight difference between the action of the Oudin and d'Arsonval currents, the former or unipolar current having a more marked focal and less marked distant action than the bipolar d'Arsonval current. For that reason, and because the action of the Oudin current is easier to control, Beer uses this current more frequently than the d'Arsonval.

F. Kidd[1] describes the urethral method of treatment. Novocain is first applied to the urethra. The bladder is then filled with 8 oz. of lotion and a catheterizing cystoscope passed. A broad electrode is placed on the patient's thigh. The active electrode, consisting of a fine metal core surrounded by insulated material except at its distal end, is passed down the cystoscope, and its tip buried in the fimbriæ of the tumour. The current is turned on for ten to fifteen seconds until the patient feels a slight pricking sensation, when the current is immediately turned off. The electrode is withdrawn and reinserted in another part of the tumour; this is repeated several times. The cystoscope is then withdrawn, and the treatment is over. The patient experiences no pain or discomfort, and is able to resume his ordinary life the next day. The above method is repeated, if necessary, three or four times, until the whole of the growth is destroyed.

In his paper the author says: "The density of the current generates sufficient heat to coagulate and destroy not only the freely waving parts of the tumour, but also the living cells in the base and pedicle of the tumour. The cells just around the electrode in the bladder are actually cauterized; they turn white, so that you see a little white area just around the electrode, but though you see no change in the deeper parts of the tumour, coagulation and death has in reality taken place, and in a few days the dead cells are thrown off." "The treatment can also be used to destroy caruncles of the urethra, and is useful in cases of carcinoma of the bladder to stop bleeding and clean up the surface of an ulcer, and so prolong the life of the patient."

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[1] *Clin. Journ.*, 1914, xliii. 232–35.

The following description of the urethral method of treatment is from Morton and Cumberbatch.[1] It should be premised that an irrigating cystoscope of the type used when the ureter is to be catheterized is required. "The electrode is a flexible wire insulated by gum elastic except at its free distal end, which terminates in a small narrow platinum button. This electrode is placed in the side channel of the cystoscope intended for the ureter catheter. The bladder is first washed out, then distended with water. The operator now illuminates the cystoscope lamp, brings a papilloma into view and passes the electrode, manipulating its free end so as to bring it into contact, wherever possible, with the base of the growth. When in position, the current is switched on and increased till the tissue whitens from coagulation. Other papillomata, if present, are treated in the same way. As soon as the contents of the bladder become cloudy, irrigation is again required. If the papilloma is bent so as to overlie its base, it must be destroyed by the diathermy, piece by piece, till the base comes into view, which then can be coagulated. Diathermy of the bladder can be performed without a general anæsthetic; the urethra is cocainized before passing the cystoscope."

Malignant disease of the tongue.—The technique employed by Mr. Herbert Frankling in the diathermic treatment of this disease, as described by himself, is as follows:

"The patient is anæsthetized with chloroform, the head being propped up, the mouth kept widely open by means of a suitable gag, and the tongue controlled by a suture placed deeply through its base.

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[1] *Op. cit.*, p. 246.

" Removal to the desired extent proceeds on ordinary lines by cutting wide of the growth with the knife electrode, the part to be divided being put on the stretch. If an area in front of the knife becomes charred and it is found impossible to get on, division of the charred tissue with ordinary scissors will put matters right. This difficulty is more readily obviated by the use of the Cumberbatch knife (p. 103).

" There is no bleeding, all vessels being sealed off as the removal proceeds : the lingual artery can be identified, as a rule, and receive special attention. Involvement of the floor of the mouth or the pillars of the fauces is easily dealt with ; we have found it easier to work near the lower jaw by this method than by the Whitehead removal with scissors.

" The area left after removal can be treated by the button electrode, special attention being paid to any tissue divided near the growth.

" We are now employing removal by the diathermic knife as a routine method for all cases of malignant diseases of the tongue and floor of the mouth, believing that any case which is operable by ordinary methods is much better treated by diathermy, and also that by it one is able to remove successfully some growths otherwise inoperable.

" The advantages which the diathermic knife offers over the scalpel in such cases are :—

" 1. *A bloodless field*, leading to more rapid and more certain operating and diminished shock. The blood-vessels are sealed as the operation proceeds. Absence of blood in the field of operation saves time and makes it easier to cut wide of the disease. Whole or partial removal of a cancerous tongue by the diathermic knife is a less formidable proceeding than when carried out by scissors or scalpel. Invasion of the floor of the mouth or the pillars of the fauces can be readily dealt with.

"2. *Destruction of any outlying malignant cells*, with consequent diminished liability to local recurrence. Since the tissues are charred and their cells killed to a certain depth, any mistake made in the direction of cutting near the growth can be rectified with greater safety at the time, or if not recognized is less liable to serious consequences. Areas where anatomical reasons prevent the surgeon from going as wide of the naked-eye lesion as he would wish can be treated at once with the button and charred to such a depth as is consistent with safety.

"3. *Diminished sepsis and septic absorption.*—Micro-organisms are killed and lymph-vessels sealed (in the same way as the blood-vessels), and diathermic removal of a growth in such a septic field as the mouth leaves a much less absorbent surface than when scalpel or scissors are used. Preoperative measures directed towards rendering the operative field more aseptic are less urgent, and so valuable time is saved.

"We have already operated on several cases by this method, finding it a simple procedure at the time and one offering an easier convalescence. The ward sisters and nurses have often told us that they no longer look upon 'tongue cases' with dread as before.

"The dissection of the glandular area is proceeded with in the ordinary manner at the usual time, and a course of prophylactic X-ray treatment should be begun as soon as possible."

The following are notes on a few cases of **malignant disease in the mouth and pharynx, etc.** General anæsthesia was used in each case. In operations in this situation ether must *not* be used as an anæsthetic, as there is risk of an explosive mixture being formed. Growths involving the naso-pharynx can be brought into view by using a suspension apparatus.

Naso-pharyngeal fibro-sarcoma.—E. B., æt 27. The disease commenced seven years ago with profuse hæmorrhage. In 1913 the patient came under the care of Mr. Steward, F.R.C.S. (Harrogate), who has kindly supplied me with notes of the history of the case. Mr. Steward, after preliminary laryngotomy, performed an extensive operation, which failed to cure the disease.

During the last four and a half years the hæmorrhage, which was at times very profuse, has been kept in check by the galvano-cautery, the entire surface of the naso-pharynx being treated once a fortnight. The chief part of the disease was situated on the posterior pharyngeal wall, covered an area about the size of half a crown, and was raised about one third of an inch above the surrounding part. The surface of the growth was smooth and showed some bleeding-points, and the disease tended to encroach on the left side of the naso-pharynx.

On September 8, 1918, the diseased area was treated by diathermy. The head of the patient was drawn well over the end of the couch. On depressing the tongue and retracting the soft palate a good view of the growth was obtained. The indifferent electrode was placed under the shoulders, and a flat disc electrode was chosen as the active electrode. This was applied for two or three seconds over every part of the surface until the whole area was thoroughly coagulated.

After this operation the patient was free from hæmorrhage for about two months, when there was a slight return of the bleeding. Mr. Steward again applied the diathermy treatment. Owing to a too vigorous application of disc and button electrodes on this occasion the anterior parts of the bodies of the second and third cervical vertebræ were injured, and the patient was ill with pyrexia running up to 103° at the end of a week. Two weeks after the operation, rough bare bone was felt all over the area treated, and the patient complained of stiffness in the neck.

Two months after the operation a large sequestrum separated; it consisted of the compact tissues of the anterior wall of the bodies of the second and third cervical vertebræ. There has been up to the time of writing no hæmorrhage since the second operation, more than twelve months ago, and there is no evidence of the growth. The patient is at present perfectly well. The slough separated between the fourteenth and twenty-eighth days.

This case serves a useful purpose in illustrating the danger of applying too vigorous diathermy over an area with subjacent bone.

Epithelioma.—H. D., æt. 46. The growth was inoperable, and involved the pillars of the fauces, soft palate, and tonsil on the left side. On September 8, 1918, Mr. Steward destroyed all the palpable and visible parts of the growth by diathermy. The posterior part of the soft palate was removed.

The operation was performed rapidly, and there was no hæmorrhage. Thick sloughs covered all the coagulated area; these separated between the fourteenth and twenty-first days. During this time the patient had great difficulty in swallowing, owing to partial ankylosis of the jaw.

No secondary hæmorrhage occurred.

In December, 1918, the patient reported with an ulcer on the lateral wall of the pharynx beyond the area treated in September. The ulcer gave rise to great pain and difficulty in swallowing. Mr. Steward coagulated the base of the ulcer with a button electrode attached to the end of the special pharyngeal electrode illustrated in Fig. 22 (p. 93). There was no discomfort after the operation, and the patient was discharged ten days later.

In another case (J. C., æt. 62), operated on by Mr. Frankling on November 28, 1918, the epithelioma involved the left half of the tongue and floor of the mouth, the whole forming a foul fungating mass. Secondary glands in the neck were removed at a separate operation.

The affected part of the tongue was removed by means of the blunt diathermy knife electrode. The root of the tongue and floor of the mouth were then thoroughly treated with a button electrode.

The operation was rapidly performed and there was almost complete absence of hæmorrhage.

After the operation very foul and tough sloughs covered the coagulated area. They separated between the tenth and sixteenth days, and the small remaining part of the tongue was smooth and healthy in appearance. There was very little pain after the operation. Secondary hæmorrhage was absent, the patient was able to talk remarkably well also, and his general health rapidly improved.

In a third case (G. K., æt. 52), also operated on by Mr. Frankling, on the same date, the floor of the mouth was extensively involved in epithelioma of the left side of the tongue. The right half of the tongue showed some leucoplakia. The operation was performed in the manner already described, and there was no operative hæmorrhage. Thick and foul sloughs, which separated between the tenth and twentieth days, covered the treated areas.

In this case a large slough was pulled off by forceps, and some hæmorrhage occurred, which was quickly stopped by a hot mouth-wash. No pain was complained of, only discomfort. After separation of the sloughs the remaining part of the tongue and the floor of the mouth had a smooth, healthy appearance, and the patient was able to speak very well.

Malignant ulceration and growths in the larynx, pharynx, œsophagus, and rectum.—In these cases special sets of electrodes are employed (Fig. 22). The electrode is made in three separate sections, which are screwed together—an ebonite handle through which passes a metal core, an intermediary piece, consisting of thin insulated steel wire, and terminal pieces of different types.

Harmer, who has had great experience of the surgical uses of diathermy, says that sepsis is not nearly so common with diathermy as after cutting operations in pharyngeal growths. He has employed this method in a large number of diseases, which include inoperable growths of the nose and throat, massive ulcers in the nose and throat, early malignant disease, rodent ulcer, innocent neoplasms, hypertrophy of the tonsils and turbinate bones, lupus, etc.

Stuart Low has shown, at the Laryngological Society, cases of inoperable malignant disease with large indurated glands treated by diathermy puncture which had been greatly benefited. He incises and reflects the cutaneous tissues over the indurated glands, and then punctures the glands with a diathermy electrode. The skin is afterwards stitched up in the ordinary way. He has found that pain has been greatly lessened and the size of the swellings much diminished.

Dan M'Kenzie[1] has obtained excellent results in the diathermic treatment of synechiæ in the nose.

With regard to the temperature reached in tissues treated by electro-coagulation, Murphy[2] says: "The temperature within the coagulated zone reaches to from 149°–158° F., while beyond this is an area $\frac{2}{5}-\frac{3}{5}$ in. thick in which there is decreasing temperature from the coagulation to the unheated portion of 149°–100° F. The temperature is as high as 932°–1112° F. on the surface of the carbonized area." Elsewhere in the same work he says that the œdema following treatment of neoplasms of the buccal cavity is often so extensive as to necessitate tracheotomy.

There is no doubt that operators by diathermy should be prepared for tracheotomy is operations involving the mouth and pharynx, but in no case that has so far come within my experience has this excessive œdema occurred.

Cumberbatch has designed, from a suggestion of

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[1] *Proc. Roy. Soc. Med.*, Laryngol. Sect., 1914–15, viii. 74.

[2] "General Surgery," ii., p. 161. 1914.

Harmer's, an active electrode suitable for operating upon tumours springing from the walls of the œsophagus and rectum, and for strictures of these tubes caused by growths. He thus describes it [1] :—“ The end piece is made of a short ebonite rod of the length and diameter of that portion of the lumen narrowed by the growth, terminating in an acorn-shaped head. The ebonite rod bears on part of its surface a metal cheek of the same length as the rod. In breadth this cheek is one quarter of the circumference of the rod. This end-piece is screwed on to the top of the intermediary piece previously described. It can be made of varying length and width to suit different strictures, the length of the intermediary piece also varying according to the position of the stricture.”

Carcinoma of the cervix.—Up to the present we have reserved the diathermic method for “ inoperable ” cases of cervical carcinoma. It is in those cases where a radical operation is negatived by some general conditions (e.g. advanced age, degenerated myocardium, cachexia), rather than by extensive local infiltration, that diathermy is most useful. Attended as it is by little loss of blood, slight shock, and diminished sepsis, it enables one to deal with cases in which other means of palliative treatment are contra-indicated.

Two methods of treatment are available : (1) The destruction by the button of as much of the cancerous mass as possible. (2) A more ambitious plan, namely a supra-vaginal amputation of the cervix by means of the diathermic knife.

The latter method should, in our opinion, be the one chosen, as it is likely to afford more lasting relief. Unfortunately, it is applicable in only a limited number of cases. We have been able in some cases to remove a cancerous cervix (even opening the peritoneum so as to get well above the diseased area), and at the same time treat outlying areas of vaginal infiltration with the button electrode, by such means freeing the patient for a time from a foul discharge and checking hæmorrhage that seemed likely to be fatal. But in the majority of cases one has to be satisfied with destroying as much as possible of the malignant mass, hoping by this means to render the condition of the patient a little more tolerable.

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[1] *Arch. Röntgen Ray*, Jan., 1915.

We think that diathermic methods may have a legitimate place in the treatment of a malignant cervix, immediately preparatory to a radical abdominal operation.

Pedunculated muco-cutaneous anal tags can be rapidly removed either with or without a local anæsthetic by transfixing their base with a suitable needle or other electrode.

When operating upon large accessible fungating growths, two active disc electrodes may be placed on opposite sides of the growth, and the diseased tissue coagulated through *en masse.*

The position of the electrodes may be altered in the case of large growths until the whole of the tumour is destroyed. The coagulated tissue may then be removed, and its base treated as described for the treatment of ulceration.

Results of surgical diathermy.—Immediately after a diathermic operation there is œdema of the surrounding tissues, accompanied by abundant exudation of lymph. In operations in the neighbourhood of the larynx, this œdema may necessitate the performance of tracheotomy. Diathermic operations involve no surgical shock, convalescence is generally rapid and painless, and usually only a slight rise of temperature occurs. The sloughs should be allowed to separate naturally and not be pulled off, or hæmorrhage may occur.

The areas from which the sloughs separate are rapidly covered with healthy granulation tissue. It is rare for adhesions to occur after diathermy. I have so far only noted this in one case, a case of malignant disease of the pharynx. In this, the button electrode was applied too long and too vigorously, the coagulation extended into the bodies of the cervical vertebræ and destroyed the surface of the bones. The surface ultimately healed over, but owing to separation of sequestra from time to time convalescence was very tedious. Suppuration, a rare complication of diathermic operations, occurred in this case.

Broncho-pneumonia is reported occasionally to follow diathermic operations upon the mouth and larynx, but so far I have not observed this complication. Judging from the reports of others, it is a far less frequent sequela than after cutting operations in this area.

The possibility of severe secondary hæmorrhage when operations have been performed in the neighbourhood of large blood-vessels must be borne in mind. This occurs when the sloughs separate.

The improvement which occurs in the general health of a patient after diathermic operations on malignant growths in the mouth and pharynx is very marked. Cases of inoperable malignant disease treated by this method should be subjected to a course of intensive X-ray therapy after the sloughs have separated. In this way life may be prolonged and some of the most distressing features of the disease avoided.

In suitable cases recurrences of the disease may be again treated by diathermy. Cumberbatch reports a case of inoperable growth of the tonsil and fauces in which the patient lived for two years and nine months after the first application of diathermy.

Pfahler of Philadelphia[1] has used diathermy extensively for the destruction of malignant disease, and combines the treatment with postoperative intensive X-ray therapy.

In certain cases X-rays are also administered before the operation. Otherwise inoperable cases of old adherent scirrhous mammæ are sometimes operated upon by diathermy.

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[1] *Journ. of Advanced Therapeutics*, 1914, xxxii. 489–520.

Clark of Philadelphia reports a case of inoperable neuro-epithelioma springing from the optic nerve in a child 9 years old, which was treated by diathermy. The patient was toxic, and collapse was impending. This case well illustrates the value of diathermy as a surgical weapon in growths considered otherwise inoperable. The tumour was very vascular, measured 20 in. in diameter, and was partly gangrenous. It was successfully removed, partly by the bipolar and partly by the unipolar method. During the operation there was practically no hæmorrhage. Heroic doses of X-rays were afterwards administered. Marked improvement in the patient's condition followed, and it was hoped that there was no metastasis. Death, however, occurred six months later from myelitis due to a secondary deposit in the lower dorsal spine. There was no local recurrence.

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